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ABSTRACT

As the fifth lesson of the Articulated Multimedia Physics Course, instructional materials are presented in this study guide. The subject matter is concerned with graphical presentations, mathematical expressions, and relationships between speed, position, and time. The content is arranged in the scrambled form, and the use of matrix transparencies is required for students to control their learning program. Students are asked to use magnetic tape playback, instructional tapes, and single concept films at the appropriate place in conjunction with a worksheet. Included are a problem assignment sheet, a study guide slipsheet, and illustrations for explanation purposes. Related documents are SE 015 963 through SE 015 977. (CC)

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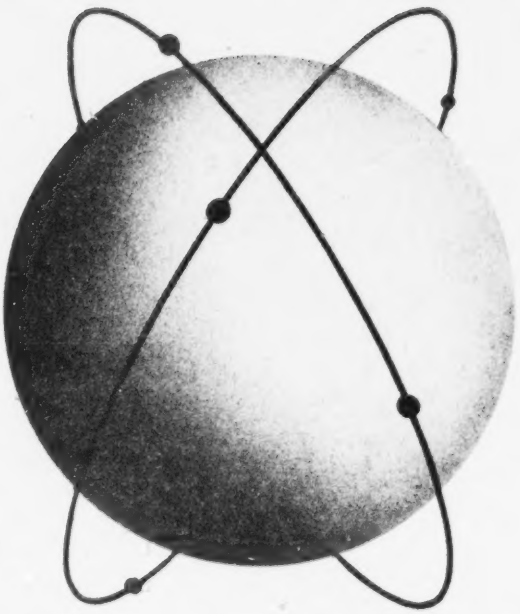
ARTICULATED MULTIMEDIA PHYSICS



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LESSON 5

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ARTICULATED MULTIMEDIA PHYSICS

Lesson Number 5

GRAPHS OF MOTION

IMPORTANT: Your attention is again called to the fact that this is not an ordinary book. It's pages are scrambled in such a way that it cannot be read or studied by turning the pages in the ordinary sequence. To serve properly as the guiding element in the Articulated Multimedia Physics Course, this Study Guide must be used in conjunction with a Program Control equipped with the appropriate matrix transparency for this Lesson. In addition, every Lesson requires the availability of a magnetic tape playback and the appropriate cartridge of instructional tape to be used, as signaled by the Study Guide, in conjunction with the Worksheets that appear in the blue appendix section at the end of the book. Many of the lesson Study Guides also call for viewing a single concept film at an indicated place in the work. These films are individually viewed by the student using a special projector and screen; arrangements are made and instructions are given for synchronizing the tape playback and the film in each case.

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New York Institute of Technology
Articulated Multimedia Physics

Lesson 5

STUDY GUIDE SLIP SHEET

STUDY GUIDE TEXT: Page 25, Notebook Entry 4(a). Draw a line through the last sentence which begins "This will be thoroughly discussed .....". This indicates that this sentence is not to be copied into your notebook.

STUDY GUIDE DIAGRAMS: Page 41, Figure 9. The interval from t_1 to t_2 on the horizontal axis is labeled "Δt_b". Cross this out and substitute for it "Δt_a".

WORKSHEETS: No corrections.

HOMEWORK PROBLEMS: No corrections.

You have learned a great deal about moving objects in your study of VECTORS. Your vocabulary now enables you to distinguish between trip length (or distance), which is a scalar quantity, and displacement, which is a vector quantity. The difference between speed and velocity is now in clear form; velocity is a vector quantity for which direction and magnitude must be stated, while speed is a scalar quantity representing the magnitude of a velocity.

In this lesson we shall be concerned with describing motion, first in graphical form and then later in simple mathematical terms. In particular, we shall concentrate on the relationships that exist between speed, position, and time.

For example, let us consider this everyday event--a motorist approaching a FULL STOP intersection. When he first sees the FULL STOP sign, he may be going so slowly that he can delay applying the brakes for a few seconds--or, his speed may be so great that the brakes must be applied at once. In either case, we could describe the motion of the car as we observe it in terms of the initial speed of the car, the distance of the car from the FULL STOP sign, time required for the automobile to stop, rate at which it loses speed approaching the intersection, and so on. This would be a description of the motion of the car without any reference to the causes of the motion or the methods used to stop the car.

Please turn to page 2.

Such a description comes under the heading of kinematics (kin uh mat iks). Hence, the subject of kinematics concerns itself only with the description of motion, not with the factors that cause motion or changes in motion. The latter comes under the heading of dynamics, which we shall reserve for a later lesson.

Although velocity and displacement, our familiar vectors, must ultimately find a place in a description of motion, it is quite possible, and in fact, considerably easier, to discuss the basic considerations of kinematics in terms of speed and distance. By restricting our language to scalar quantities, at least at the beginning, we will not need to worry about directions. Once the concepts involved in kinematics are firmly implanted, we shall be able to swing into the more difficult notions of vectorial changes in motion.

You will discover that you already know something about kinematics. Somewhere in school you learned the relationship:

distance = rate x time

Probably you worked simple problems with the help of this equation. We shall start by refining this.

Please turn to page 3.

Exactly what is meant by "rate"? An auto may move at a steady or constant speed, or it may pick up and lose speed over a given trip. If the latter, its speed is variable. In the expression, distance = rate x time, as you used it in the past, rate was taken to mean unchanging or constant speed. For the present we shall also agree that unless otherwise stated, speed will be considered constant.

Since we will be using this relationship in calculations, we want to write it in convenient symbolic form. We shall write it like this:

$$d = vt$$

In this equation, d = distance or trip length, v = speed, and t = time. All these quantities are scalars and so there are no arrows or half-arrows capping the symbols.

Before concluding this introduction, we should like to mention one other point. Many textbook authors use the sumbol s (space), for distance rather than d. You may therefore encounter the equation written this way:

$$s = vt$$

Here, s = distance or trip length. As long as we are consistent, it makes no difference which symbol we use for distance. We have chosen d rather than s because we feel that d is more closely associated with the word it represents--distance. When you have gained facility in kinematics you will be able to substitute any symbol for any other without confusion.

Please turn to page 4.

The relationship between distance d, constant speed v, and time t is given by this equation:

$$d = vt$$

To use this equation correctly, we must first become very conscious of the importance of consistent units. For instance, if an auto moves at a constant speed of 40 miles per hour (or 40 mi/hr) and travels for 3 hours, how far will it go? First we look the units over carefully. Are they in the same system, English or Metric? Are they of the same nature? That is, if the speed if given in mi/hr, is the time also given in hours rather than in minutes or seconds? In this example, the units are obviously consistent so we can say:

$$d = vt$$

Substituting: $d = 40 \text{ mi/hr} \times 3 \text{ hr}$

$$d = 120 \text{ mi}$$

Now, how about this one? If an auto moves at a constant speed of 40 mi/hr and travels for 3 minutes, how far will it go? The time units are now inconsistent. What should we do? We could convert the speed to miles per minute, or we could convert the time to a fraction of an hour. Let's adopt the latter alternative and convert the time to a fraction of an hour this way:

$$3 \text{ min} \times \frac{1 \text{ hr}}{60 \text{ min}} = 1/20 \text{ hr}$$

So: $d = 40 \text{ mi/hr} \times 1/20 \text{ hr} = 2 \text{ mi}$

Please turn to page 5.

Here's a sample for you to try, applying the same principles. A toy electric train has a constant speed of 4 ft/sec. How far will it go if allowed to run for 10 minutes?

Work out this problem on scrap paper, showing units at all times, and then select the correct answer below.

(1)

A The train will cover a distance of 2400 feet.

B The train will cover a distance of 240 feet.

C The train will cover a distance of 150 feet.

At this point, we feel that you have sufficient experience in using the Study Guide to make it unnecessary for us to replicate a question-page diagram on any other page. Thus, it is a good idea to keep your finger on the diagram page as you turn to the referral page, should you need the diagram again.

YOUR ANSWER --- C

You are correct. The heavy straight line is the curve of the motion. (Note that we use the word curve in its most general sense. Since a straight line is merely a special case of a curved line, we refer to both as curves.)

In Figure 1, the curve is parallel to the X-axis, neither rising nor falling. This means that the speed is constantly 35 mi/hr throughout the time interval of the graph.

Refer now to Figure 2.

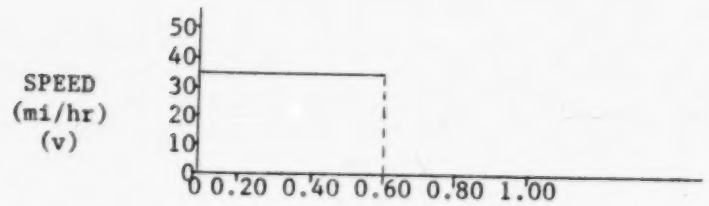


Figure 2

In essence, this is the same graph as that of Figure 1. However, here we have "stopped" the motion of the car after 0.60 hr has passed. We now ask the question, "How far has the car journeyed during this 0.60 hr interval?"

(3)

A 2.1 mi.

B 21 mi.

C 210 mi.

YOUR ANSWER --- B

You are correct, of course. The area under CD is greater than the area under AB; hence, the graph shows that the greater distance was covered by the car during trip CD.

Please turn to page 8 for a notebook entry.

NOTEBOOK ENTRY

1. Motion with Uniform Speed

(a) Speed is defined as the rate of change of position or distance per unit time. In the English system, speed may be measured in mi/hr, or ft/sec. In the MKS system speed may be measured in km/hr, m/sec, cm/sec, or variations of these.

(b) Distance, speed, and time for a body moving uniformly with constant speed are related by the expression: $d = vt$. Here d = distance, v = speed, and t = time.

(c) The equation $d = vt$ may be stated in two other forms:
$v = d/t$ if v is the unknown.
$t = d/v$ if t is the unknown.

(d) In a v-t graph, the area under the curve represents the distance covered by the moving body, if its speed is v and it travels for time t.

(e) Example: Figure 4 (copy). This graph shows a body moving at a uniform speed of 60 mi/hr. If allowed to travel for 0.75 hr. the distance covered would then be 45 mi. This answer may be obtained directly from $d = vt$ or by calculating the area under the curve in terms of the scale divisions.

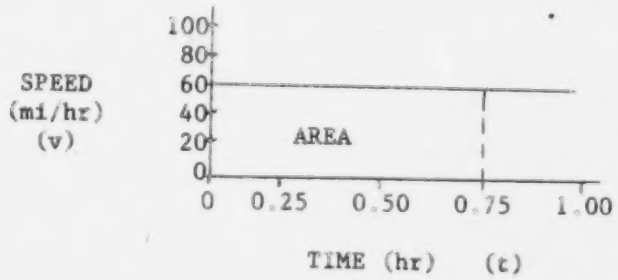


Figure 4

Working with Figure 4, how much time would be required for this object to travel 300 miles?

Write your answer; then turn to page 62 to check it.

YOUR ANSWER --- B

You are correct. The car starts from rest at point A, and gains speed. After 0.010 hr (36 seconds), its speed is 10 mi/hr. After 0.020 hr (1 min. 12 sec) its speed is 20 mi/hr, and so on until after 0.060 hr it attains a final speed of 60 mi/hr at point B. Thus, the speed is varying because it does not remain constant. On the other hand, after 0.060 hr, the auto maintains a constant speed of 60 mi/hr.

Now we can define average speed in a rather simple way. The average speed of a body moving with varying speed is the ratio of the distance it travels to the time required for the trip. As an illustration, consider an airliner flying from Chicago to Washington, a distance of 600 miles. This particular airline has scheduled stops at Fort Wayne, Indiana and Morgantown, West Virginia. As a result of landings and takeoffs, plus unpredictable winds, the speed of the plane varies widely over the trip. If on a given day the trip requires exactly 3.00 hr, what was the average speed of the plane?

To check your answer, please turn to page 63.

YOUR ANSWER --- C

There has to be a definite relationship! Would you ever say that your term average in American History, for example, is not related to the highest or lowest marks you received on tests during the semester? Every test you take has a bearing on your final average. Your final average, if computed honestly and fairly, must take all individual grades into account, weighting them properly as we have explained before.

The same is true of average speed. The speed driven during every interval of the car's trip must play a role in determining the average speed.

Please return to page 64 and select another answer.

YOUR ANSWER --- C

You are correct. Good thinking. If the motion of a body is such that its v-t curve is a straight line, then and only then may $\bar{v} = v/2$ be used to find average velocity.

NOTEBOOK ENTRY

2. Average speed

(a) The average speed of a body starting from rest and moving regularly or irregularly may always be found from the ratio of distance to time: $\bar{v} = d/t$.

(b) The average speed of a body starting from rest is given by the expression: $\bar{v} = v/2$.

Here, v is the final velocity, provided that the speed of the body changes uniformly. This means that the body must pick up equal amounts of speed in equal times.

(c) The v-t curve of a body that gains or loses speed uniformly is always a straight line. If the body starts from rest, the v-t curve must go through the origin of the axes.

In review, study the five diagrams in Figure 7; then answer the following question.

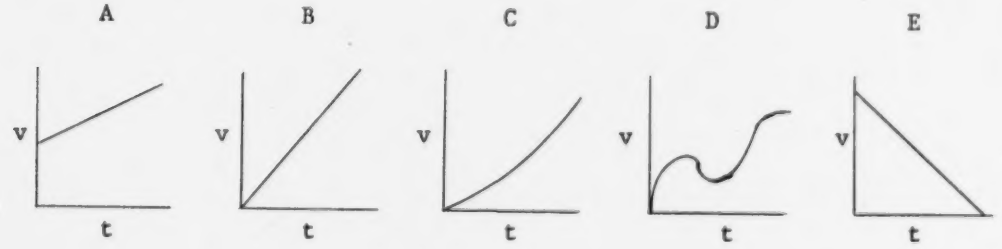


Figure 7

The diagram or diagrams which show an object moving with uniformly changing speed is (are) _____.

Write your answer; then turn to page 38 to check it.

YOUR ANSWER --- C

You are correct. If you selected this answer on the first try, you're doing very well.

At this time we want to delve somewhat more deeply into straight and curved v-t graphs.

Refer to Figure 8. Two time intervals are shown on the X-axis. The first interval is the length of time between t_2 and t_1 and is the difference between them. If t_1 occurs 2 sec after the start of the timing, and t_2 occurs 4 sec after the same zero point, then the interval is $t_2 - t_1$ = 4 sec - 2 sec = 2 sec. There is a standard way of indicating intervals in physics: We use the Greek letter Δ (Delta) before the symbol. In this case, the interval $t_2 - t_1$ might be symbolized as Δt_a. The subscript "a" here merely identifies this particular interval as distinct from some other interval we may mention later. (Practice reading out "Δt_a" as "delta T sub A.")

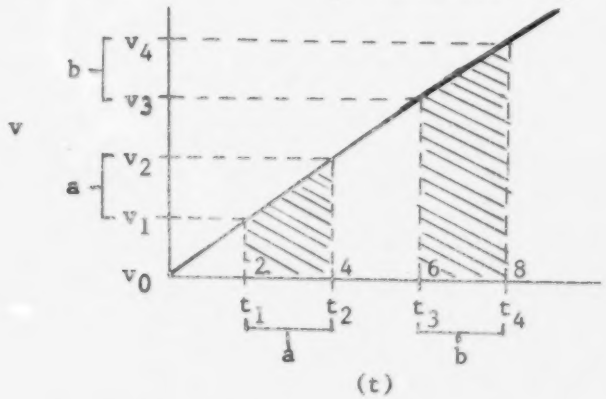


Figure 8

Please turn to page 13 to continue.

The Δ symbol is ordinarily used to signify a change in something. An interval of time such as Δt_a is really the change in time from t_1 to t_2. In the subtraction, $t_2 - t_1 = \Delta t$, we place the t_2 first, because it is a larger number (having occurred later). In this way, we avoid unnecessary minus signs.

Which one of the following would be a sensible label for the interval $t_4 - t_3$ in Figure 8 on page 12?

(11)

A Δt_a.

B Δt_b.

C t_b.

D I don't quite understand how the "Δ" is used.

YOUR ANSWER --- A

Before you think in terms of "sooner" or "later," you ought to note that both curves pass through the origin of the axes at zero time. The interpretation of this is that neither car had covered any distance when the timing began, since the origin also means zero distance.

But, if neither car had covered any distance when the timing began, then neither one could have started moving sooner than the other.

Please return to page 71 and select another answer.

YOUR ANSWER --- A

This answer is incorrect. Curve 2 in this graph--(4) on page 56--has a steeper slope than curve 1 because it rises faster per unit time than the other. Since the slope of a curve represents the speed of the moving body, these objects are not traveling with the same speed.

Please return to page 56 and select another answer.

YOUR ANSWER --- A

You are correct. The ratio of change of distance (Δd) to the time interval (Δt) is called the slope of the curve.

O. K. Now let's prove that this ratio must give the speed of the moving body. We'll do this in two ways.

First, if you look back at your notebook definitions, item 1(a), you will see that speed is defined as the rate of change of position, or distance per unit time. Since Δd is the change of distance and Δt expresses the time interval corresponding to this change of position, then $\Delta d/\Delta t$ is really the rate of change of position. Hence, it is equal to the speed.

Second, suppose we assign units to the two axes. The time axis will be divided into hours and the distance axis into miles. Since Δd must be measured in miles or in fractions of miles, and Δt must be measured in hours or fractions of hours, then the ratio $\Delta d/\Delta t$ must come out in miles/hour. Of course this compound unit is our familiar measure of speed, hence $\Delta d/\Delta t$ must represent speed.

NOTEBOOK ENTRY

3. Distance-time relations

(a) Distance-time relations may be shown by a d-t graph. (copy Figure 13 on page 98 as an example).

(b) On a d-t graph, speed is shown by the slope of the curve, slope being defined as the ratio $\Delta d/\Delta t$.

Please go on to page 17.

Let's see how our newly-gained knowledge can be put to use in analyzing curves of motion. Refer to Figure 14.

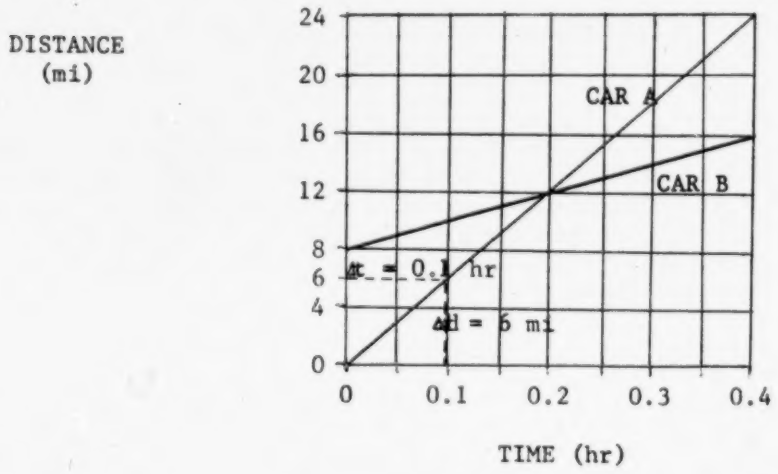


Figure 14

We need to know, first of all, whether or not both cars are traveling with uniform speed. On the basis of our previously acquired knowledge, we can readily say that both cars are moving with uniform speed because their d-t graphs are both straight lines.

Next, we shall want to compute the speed of each car. The broken lines have been drawn to help you determine the slope of the curve for Car A.

Since $\Delta d = 6$ mi and $\Delta t = 0.1$ hr, what is the speed of Car A? (NOTE: you may use any other value for Δd and the corresponding value for Δt. As long as corresponding values are used, the slope will come out the same. Try it for yourself, if you like.)

(18)

A The speed of car A is 6 mi/hr.

B The speed of car A is 60 mi/hr.

C I don't know how to determine the speed of Car A.

YOUR ANSWER --- A

You are correct. Please continue to keep your notebook in good shape.

When you drive a car at a constant speed, the distance is proportional to the time. All this means is that if you double your driving time you will go twice as far, if you triple your time you will go three times as far, etc. If you know the speed, then it is an easy matter to determine the distance for various trip times. Suppose we set up a table showing distance-time relations for a constant speed of 30 mi/hr.

Elapsed time	Distance	
0.10 hr	3 mi	(d = vt = 30 mi/hr x 0.10 hr)
0.20 hr	6 mi	(etc.)
0.30 hr	9 mi	(etc.)
0.40 hr	12 mi	
0.50 hr	15 mi	
0.60 hr	18 mi	

We have graphed v-t relations before. But now we have a table showing d-t (distance vs. time) relations. How would such a graph look?

The best way to answer this question is to plot the graph for the agove example. As before, time (t) is the X-axis but, this time, distance (d) is the Y-axis.

Draw this graph on linear graph paper, if it is available. Then compare it with our graph by turning to page 71.

YOUR ANSWER --- A

You are correct. In the solution shown in Figure 15 below, we selected t as 0.2 hr. This makes Δd = 12 mi - 8 mi = 4 mi. Hence, the slope (and speed) for car B is 4 mi/0.2 hr = 20 mi/hr.

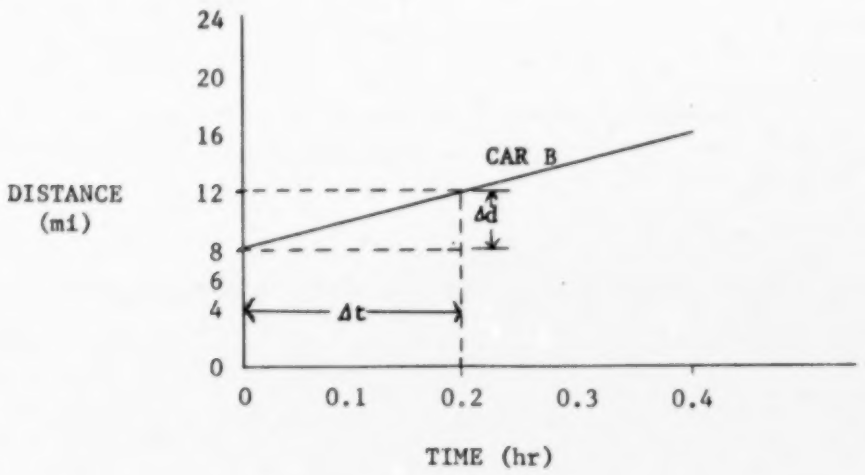


Figure 15

Referring again to Figure 14 on page 17, and assuming that both cars are traveling the same road in the same direction, how far ahead of Car A was Car B at the start of the timing period?

Write your answer; then turn to page 106 to check it.

YOUR ANSWER --- B

No, this answer is not right, but we believe we can follow your reasoning. You know that car B started at a point 8 mi ahead of car A. (Refer to Figure 14 on page 17). This is quite true. Now, if car B had remained still, car A would then have had to travel 8 mi to come even with it. But car B was not motionless. We calculated its speed as 20 mi/hr, you will remember. Thus, after car A had traveled 8 mi toward car B, when it arrived at this point it would find that car B had moved farther along the road.

This reasoning should give you a helpful clue. Ask yourself whether car A must have traveled more or less than 8 mi under these circumstances to catch up with car B.

Please return to page 106 and select a better answer.

YOUR ANSWER --- C

Think back to our discussion of displacement in the lesson on vectors. Suppose a car is driven northward 10 miles, then is turned around and driven southward 3 miles. The resulting total displacement is, of course, 7 miles from the original point of departure.

You should recall that the resultant of two collinear vectors is always found by adding the magnitudes algebraically. In the above example, what would you have to do to the 3 mi displacement so that, when it is algebraically added to the 10 mi displacement, the resultant will be 7 mi?

We hope that this has "tuned you in" correctly that you can now return to the original question and choose the right answer.

Please return to page 49 and select the correct answer.

YOUR ANSWER --- A

There is a very serious error in diagram (1). Although this purports to be a graph, it is actually nothing of the sort. Here is the reason.

Refer to diagram (1) of Figure 17 on page 107. The t-axis of a d-t graph indicates the passage of time. Despite the claims of science-fiction writers, time "flows" only in one direction; that is, forward. Time is a true scalar quantity as we use it in physics, and it will continue to be considered as such until we invent a time machine to give man the ability to travel into the past. Negative time has absolutely no meaning.

Now as you study Figure 17(1) you will observe that line segment 3 appears to carry the description of the motion backward in time, or toward the origin. You will never see a d-t graph plotted for real quantities that accomplishes this. In a d-t curve, coordinates that represent events occurring later than previous ones must be placed to the right of the previous ones. Thus, line 3 which presumably represents the return trip, should slant the other way to show that the return trip occurred after the outgoing trip.

Please return to page 107. Keep the above discussion in mind as you make your next selection.

YOUR ANSWER --- B

You are correct. The minus sign merely tells us that the car was traveling in the opposite direction from that of the car going away from its starting point. We know that stating a speed as a minus quantity, for instance, minus 40 mi/hr, seems peculiar. But when interpreted correctly it loses its strangeness.

Before continuing, please turn to page 131 in the blue appendix.

NOTEBOOK ENTRY

(Item 3)

(c) The slope of a d-t curve is positive (+), if the distance from the starting point increases with increasing time. Such a curve climbs as it is drawn from left to right. Figure 18 on page 79 is an example of a d-t curve with positive slope and, hence, positive speed. (Copy it.)

(d) The slope of a d-t curve is negative (-) if the distance from the starting point decreases with increasing time. Such a curve descends as it is drawn from left to right. Figure 19 on page 79 is an example of a d-t curve with negative slope and, hence, negative speed. (Copy it.)

Which of the following is true of a moving body having a negative speed?

(24)

A Its speed is increasing.

B Its speed may be constant, but its direction of motion is opposite that of the direction previously designated as positive.

C Its speed is decreasing.

YOUR ANSWER --- B

Did you read the problem carefully? How long did it take the cart to reach the bottom of the plane? It was 4 sec, wasn't it? During this entire interval, the cart was accelerating uniformly, picking up the same amount of added speed during each second.

Since the final speed was 8 ft/sec, and the cart required 4 sec to reach it, the acceleration could not have been 8 ft/sec for each second.

Suppose you had a cart that did accelerate 8 ft/sec in each second. Then:

At the end of the first second its speed would be 8 ft/sec.
At the end of the second second, its speed would have risen to 16 ft/sec (since it gained 8 ft/sec during this second).
At the end of the third second, its speed would have risen to 24 ft/sec (for the same reason as above).
At the end of the fourth second, its final speed would be 32 ft/sec.

Please return to page 52 and select a more reasonable answer.

YOUR ANSWER --- A

You are correct. The general formula for slope is the ratio $\Delta y/\Delta x$. In this example, the Y-axis is the v-axis and the X-axis is the t-axis. Hence, the slope = $\Delta v/\Delta t$.

A few moments ago, we found the acceleration of the cart in Figure 21 on page 121 to be 2 ft/sec^2 by using ordinary logic. Now suppose we find the slope of the graph in Figure 21 and compare this answer with the one we arrived at by logic.

$$\text{Slope} = \frac{\Delta v}{\Delta t} = \frac{2 \text{ ft/sec}}{1 \text{ sec}} = 2 \text{ ft/sec}^2$$

Both answers are the same. Now we are ready to define acceleration in very rigorous terms.

NOTEBOOK ENTRY

4. Acceleration

(a) Acceleration is defined as the rate of change of velocity per unit time. At this point we abandon the use of the word "speed" in favor of "velocity" because it turns out that acceleration must be handled strictly as a vector quantity. This will be thoroughly discussed in a forthcoming lesson.

(b) Mathematically, acceleration is: $a = \Delta v/\Delta t$. For the time, we may omit the arrow over the "a."

(c) Since $\Delta v/\Delta t$ = slope of the v-t curve, then for uniform acceleration we may write a = slope of v-t curve.

Please go on to page 26.

With the definition of acceleration firmly in mind, solve the following problem:

A car going at 20 mi/hr accelerates uniformly to 60 mi/hr in 6.0 sec. What is the acceleration of the car along the road?

(27)

A 10 mi/hr-sec.

B 10 mi/hr^2.

C 6.7 mi/hr-sec.

D 6.7 mi/hr^2.

You have now completed the study portion of Lesson 5 and your Study Guide Computer Card and AV Computer Card should be properly punched in accordance with your performance in this Lesson.

You should now proceed to complete your homework reading and problem assignment. The problem solutions must be clearly written out on 8½" x 11" ruled, white paper, and then submitted with your name, date, and identification number. Your instructor will grade your problem work in terms of an objective preselected scale on a Problem Evaluation Computer Card and add this result to your computer profile.

You are eligible for the Post Test for this Lesson only after your homework problem solutions have been submitted. You may then request the Post Test which is to be answered on a Post Test Computer Card.

Upon completion of the Post Test, you may prepare for the next Lesson by requesting the appropriate

1. study guide
2. program Control Matrix
3. set of computer cards for the lesson
4. audio tape

If films or other visual aids are needed for this lesson, you will be so informed when you reach the point where they are required. Requisition these aids as you reach them.

Good Luck!

This page has been inserted to maintain contin continuity of text. It is not intended to convey lesson information.

YOUR ANSWER --- A

You are correct. The solution is:

$$d = \underbrace{(4 \text{ ft/sec} \times 60 \text{ sec/min})}_{\text{CORRECTED } v} \times 10 \text{ min}$$

$$d = 2{,}400 \text{ ft.}$$

There are many situations in which we have to determine the time t of a trip, or in which we are asked to find the speed v of a moving object, the other factors being given. In such problems, it is best to rearrange the equation in its symbol form (that is, before substituting numbers) so that the unknown is isolated to the left of the equal sign.

From simple algebra you know that:

If $d = vt$, then $v = d/t$ and also $t = d/v$

In illustration: How long does it take an automobile to go from city A to city B, a distance of 180 km, if it maintains a constant speed of 60 km/hr? (Don't substitute in $d = vt$. Solve the symbol equation for the unknown, t, as shown above, and then substitute the numbers directly into this form.)

Write your answer and check it by turning to page 86.

YOUR ANSWER --- A

The heavy straight line is the curve of the motion. (Note that we use the word curve in its most general sense. A straight line is merely a special case of what we normally call a curved line.) Using the graph in the normal way, we note that after 0.20 hr has passed, the speed is 35 mi/hr just as it was initially. At 0.40 hr, the speed is still 35 mi/hr. The same is true after the whole hour has gone by. That is, the curve is parallel to the X-axis, neither rising nor falling.

How, then, would you describe a speed which did not change after any amount of time had passed within the limits of the graph?

Please return to page 86 and select another answer.

YOUR ANSWER --- A

Watch that decimal point! You correctly used the relation d = vt to find the distance, but in multiplying 35 mi/hr (v) by 0.60 hr (t), you did not place the decimal point correctly.

Be careful of the decimal point in your next choice. Please return to page 6.

CORRECT ANSWER: The area under the curve is 21 miles.

The area of a rectangle is found by multiplying length times height. The height in this case is 35 mi/hr and the length is 0.60 hr; hence the area is 0.60 hr x 35 mi/hr, or 21 mi.

This result may bother you if you are a mathematical purist. Since when, you say, can an area be measured in miles? Doesn't an area have to be in square miles or square feet or square meters? Let's beat this idea around a bit more.

Sure, an area is usually measured in square length units. But in this case, the area represents a distance because of the scaled units we used. Your mathematics teacher would be quite disturbed if you said that the area under the curve equals 21 mi. but he wouldn't bat an eye if you said that the area represents 21 mi. And, come to think of it, when you scaled a displacement of, say 100 mi down to a 10 cm line segment in the last lesson, didn't you do it on the basis of the scale 1 cm = 10 mi? Of course 1 centimeter can't be equal to 10 mi. What you really mean is that 1 cm represents 10 mi.

Please turn to page 33.

Now we'll analyze Figure 3. During trip AB, a car moves 30 mi/hr for an interval of 0.25 hr. Then there is a sudden increase of speed from B to C. The car proceeds for another half hour at a speed of 50 mi/hr. To find the total distance traveled by the car, we used d = vt to determine the individual distances at the two different speeds, and then add the distance thus obtained.

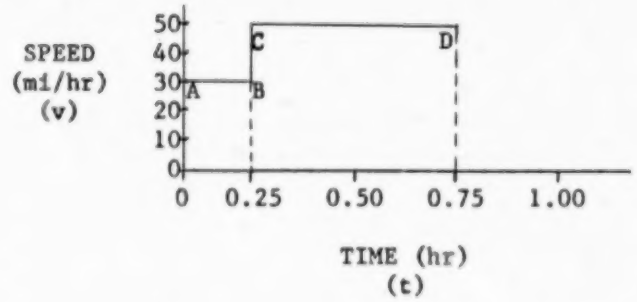


Figure 3

All right. Let's do it. Find the total distance covered by the car in the two trips shown in Figure 3. (You may ignore significant figures in this calculation.)

What is the total distance?

(4)

A 30 miles.

B 32.5 miles.

YOUR ANSWER --- A

Absolutely not! The long 45-minute test must have surveyed a substantial amount of required course material. By getting 95%, you proved that you had mastered a great deal of the work.

The short 5-minute quiz must have covered much less work than the longer one. Your low mark on this test showed that you had failed to master a very small part of the work. Certainly the long test should carry much more weight than the short one in determining your average worth as a student for the whole marking period.

This example is similar to our original trip problem.

Please return to page 88 and select the correct answer.

YOUR ANSWER --- A

Incorrect on both counts! The car starts from rest at point A just as the timing starts. Its speed and distance are both zero at this point. One one-hundredth of an hour (0.010 hr) later, the speed is 10 mi/hr; after a similar interval of 0.010 hr, the speed has risen to 20 mi/hr. Thus it goes until a total of 0.060 hr has passed when we find the car moving with a speed of 60 mi/hr, the maximum it is destined to reach in this example.

When we call anything uniform, including speed, we mean it does not vary from second to second and minute to minute. As each second passes during the first 0.060 hr interval, the speed of the car increases. Clearly, the speed cannot be uniform over AB.

The second error in the answer relates to BC. We have seen that distance is represented by the area under a v-t curve, not by the curve itself. Thus, BC cannot show a distance, uniform or otherwise.

Please return to page 62 and select another answer.

YOUR ANSWER --- A

You are correct. We have shown that average speed is the ratio of total distance to time, or $\bar{v} = d/t$. Look at the tabulated values:

	Speed	Time	Distance
(1)	rises from 0 to 60 mi/hr	0.05 hr	1.5 mi
(2)	constant at 60 mi/hr	0.05 hr	3.0 mi

From these values, we can substitute and obtain:

$\bar{v} = \frac{1.5 \text{ mi}}{0.05 \text{ hr}} = 30$ mi/hr, which is <u>half</u> the final speed.

Reviewing briefly, we have the following relationships:

For a body traveling with <u>constant</u> speed: $d = vt$.

Average speed of a body that picks up speed smoothly and uniformly starting from rest: $\bar{v} = d/t$, and also: $\bar{v} = v/2$, where v = final speed, and $\bar{v}$ = average speed.

As a test of your comprehension, try this one. A certain motorcycle racetrack, shaped like a figure 8, is 12.4 mi in total length. To qualify as an entry, a motorcyclist must run a 10-lap heat in 1.80 hr. What average speed must he maintain to qualify?

Write this out; then turn to page 92 to check the answer.

YOUR ANSWER --- A

On the face of it, the above statement is correct, but you have missed the point completely.

Actually, the final speed is implicit in the problem. At the end of the 10-lap heat, the motorcyclist returns to his starting point and comes to rest. Hence, his final speed is zero! But this does not help us determine his average speed.

Think a bit. What kind of motion is demanded if you want to use $\bar{v} = v/2$? Is the motorcyclist obliging you with the kind of motion that must occur if this expression is to be applicable? No, he is not.

Now, please return to page 92 and select another answer.

CORRECT ANSWER: The diagrams which show an object moving with uniformly changing speed are (A), (B), and (E).

We have said that a v-t curve shows uniformly changing speed if it is a straight line. The straight line tells you that the moving body is gaining or losing equal amounts of speed in equal intervals of time. Since (A), (B), and (E) are straight lines, they all show an object moving with uniformly changing speed.

Before continuing, please turn to page 129 in the blue appendix.

Three of the diagrams in Figure 7 on page 11 show various motions in which the body starts from rest. Which three are they?

Write your answer; then turn to page 66 to check it.

CORRECT ANSWER: Diagram (D) shows that the body is gaining and losing speed alternately during its trip. When the v-t curve rises as it moves to the right, the speed is increasing. When the v-t curve drops as it moves to the right, this is a sign of decreasing speed.

Refer to diagram (C) of Figure 7 on page 11. Which of the following statements is true?

(10)

A The body starts from rest, then maintains a constant speed.

B The body starts from rest, then gains speed uniformly.

C The body starts from rest, then gains speed non-uniformly.

YOUR ANSWER --- A

Hardly. Since we have already identified the first interval in Figure 8 on page 12, $t_2 - t_1$, as Δt_a, we shall want a different subscript for the second interval, $t_4 - t_3$. The purpose for using the subscript "a" is to identify this <u>particular</u> interval between the 4 second mark and the 2 second mark. We must then avoid using the same subscrip for any other interval.

Please return to page 13 and select another answer.

YOUR ANSWER --- A

You are correct. As is clear from the graph of Diagram 8 on page 12, if the two time intervals a and b are equal in duration, then for a straight-line graph, the two corresponding changes in speed will also be equal.

This is exactly what we meant when we said that a straight-line v-t graph always indicates that the speed is changing in a uniform manner.

Now let's see how a curved-line graph, such as that in Figure 9, differs in important details. Again, we have carefully equalized the two time intervals Δt_a and Δt_b. We then drew vertical bounding lines up to intersect the curve and projected them horizontally to the v-axis.

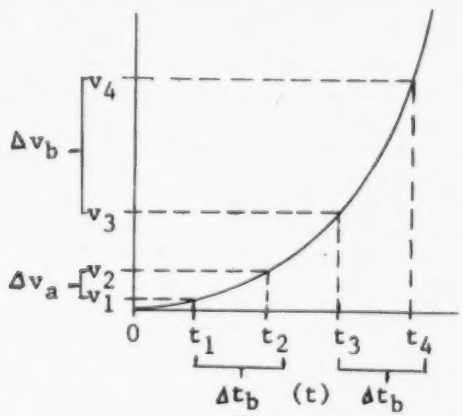


Figure 9

In a v-t graph which is a curved line, which one of the following describes correctly what is apparent from an examination of the graph? (Note: the symbol $\neq$ means "is not equal to.")

(13)

A If $\Delta t_a = \Delta t_b$, then $\Delta v_a = \Delta v_b$.

B If $\Delta t_a = \Delta t_b$, then $\Delta v_a \neq \Delta v_b$.

YOUR ANSWER --- C

This answer is incorrect. One of the first things that strikes the eye as you view the drawing of figure 11 on page 71 is that both graphs are straight lines.

We have emphasized several times that a straight line indicates a direct proportion. In this case, each car covers equal distances in equal times, so both of them are moving with constant or uniform speed.

Please return to page 71 and select another answer.

YOUR ANSWER --- B

This answer is not correct. Curve 2 in this graph--(3) on page 56--has a steeper slope than curve 1 because it rises faster per unit time than the other. Since the slope of a curve represents the speed of the moving body, these objects are not traveling with the same speed.

Please return to page 56 and select another answer.

YOUR ANSWER --- B

You didn't read the verbal definition carefully enough. We define slope as the ratio of the distance "up" the d-axis to the distance "along" the t-axis.

The ratio you chose is the reverse of this. You have given us the ratio of the distance "along" the t-axis to the distance "up" the d-axis.

Please return to page 98 and select another answer.

YOUR ANSWER --- B

This is the correct answer. Just by considering the slope, we can write $\Delta d/\Delta t = 6$ mi/0.1 hr = 60 mi/hr. This is the speed of Car A.

Now, how about the speed of car B? You will want to determine this for yourself, but we'll help you out with a little precaution. You'll notice that the graph for car B does not start at the origin. This makes a difference in determined the change of distance with time. Select a convenient value for Δt; then find the corresponding value of Δd. Calculate the slope of the car B curve. Refer to Figure 14 on page 17.

What do you find as the speed of car B?

(19)

A The speed of car B is 20 mi/hr.

B The speed of car B is 30 mi/hr.

C The speed of car B is 60 mi/hr.

YOUR ANSWER --- B

You are correct. The "Δ" signifies "a change in"; the "t" states that you are talking about time, and the subscipt "b" simply distinguishes this interval from the one you previously designated as "a."

You remember that we started this discussion for the purpose of comparing straight- and curved-line graphs. Let's first talk about the straight type. In Figure 8 on page 12, the two shaded time intervals are made equal so that:

$$\Delta t_a = \Delta t_b = 2 \text{ sec}$$

Vertical lines have been drawn to intersect the curve from the beginning and end of each interval. When the corresponding horizontal lines are carried over to the "v" axis, we can then see instantly how the speed has changed in each of these two intervals of time. It is almost self-evident that, in a straight-line graph, the change in speed for one interval is exactly the same as the change in speed for any other equal interval.

In a straight-line v-t graph, which of the following best expresses this idea?

(12)

A If $\Delta t_a = \Delta t_b$, then $\Delta v_a = \Delta v_b$.

B If $t_a = t_b$, then $v_a = v_b$.

YOUR ANSWER --- B

No excuses, please. You have not taken careful notes. Here's a good chance to catch up, and take the notes carefully.

Go on to page 48.

Here is the notebook entry again.

NOTEBOOK ENTRY
Lesson 5

1. Motion with Uniform Speed

(a) Speed is defined as the rate of change of position, or distance per unit time. In the English system, speed may be measured in mi/hr, or ft/sec. In the MKS system speed may be measured in km/hr, m/sec, cm/sec, or variations of these.

(b) Distance, speed, and time for a body moving uniformly with constant speed are related by the expression: $d = vt$, in which d = distance, v = speed, and t = time.

(c) The equation $d = vt$ may be stated in two other forms:
$v = d/t$ if v is the unknown;
$v = d/v$ if t is the unknown.

(d) In a v-t graph, the area under the curve represents the distance covered by the moving body, if its speed is v and it travels for time t.

(e) Example: Figure 4 (copy).

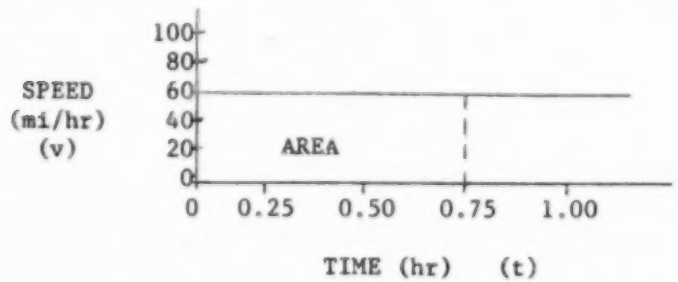


Figure 4

The graph shows a body moving at a uniform speed of 60 mi/hr. If allowed to travel for 0.75 hr, the distance covered would then be 45 mi. This answer may be obtained directly from $d = vt$ or by calculating the area under the curve in terms of the scale divisions.

Please return to page 70 and select the correct answer.

YOUR ANSWER --- C

You are perfectly correct. The intersection of the two curves represents the point at which both cars are equidistant from the origin. Thus, this is the location where car A must catch up with car B. Since the intersection occurs 12 mi from the starting point, this is the answer.

Before continuing, please turn to page 130 in the blue appendix.

Throughout this lesson we have discussed distance and speed as scalar quantities. You have learned, however, that when we worry about the direction of either of these quantities, we must begin to think in terms of vectors. In the simplest form of vector problem with which we have dealt, we concerned ourselves with collinear vectors, or vectors that lie on the same straight line either in the same or in opposite directions.

Do you remember how we distinguished a given direction of a vector from the opposite direction assigned to another vector? If you do, you'll have no trouble selecting the right answer to the question below.

How are opposite directions indicated in writing (not graphing) the values and directions of two vectors?

(21)

A We label one of them "a" and the other "b."

B We assign a (+) sign to one and a (-) sign to the other.

C I don't remember how this is done.

YOUR ANSWER --- C

No, it isn't. In choosing diagram (3) of Figure 17 on page 107, you didn't compare the car's speed when it was "going" with its speed when it was "returning." The trip from A to B was made in 0.2 hr while the trip back from B to A required more time, that is, 0.35 hr. Therefore, the average speed of the car on return was less than its speed on the outgoing trip.

Since speed in a d-t curve is shown by slope, and since the speed along line segment 1 was greater than that along line segment 2, which of these two lines should have the steeper slope? Is the diagram correct in this respect?

You should now be able to choose the best graph with no difficulty.

Please return to page 107 and select another answer.

YOUR ANSWER --- A

The minus sign, as in v = -20 km/hr, does not indicate a changing speed. It is perfectly possible for a straight-line d-t graph to have a negative slope, as we have just seen, yet such a graph describes motion with constant speed because it is a straight line.

The use of algebraic signs with quantities such as distance and speed symbolizes changed direction, nothing more.

Please return to page 23 and select the correct answer.

CORRECT ANSWER: The car picks up 6 mi/hr during each second of its travel.

This expresses the acceleration of the car. We may write it in several different ways:

acceleration = 6 mi per hr per sec
or acceleration = 6 mi/hr per sec
or acceleration = 6 mi/hr/sec
or acceleration = 6 mi/hr-sec (This is the most useful way.)

However it is written, it is always read as "Six miles per hour per second." It will help to pause before the second "per" like this: "The acceleration is 6 miles per hour_(pause) per second." The pause will help you remember that the body is picking up speed at the rate of 6 miles per hour--for each second it travels.

A toy cart rolling down an inclined plane (sloping plank) from a motionless start has a speed of 8 ft/sec as it reaches the bottom, having taken 4 sec to traverse the plane. What is its acceleration?

(25)

A 2 ft/sec-sec.

B 8 ft/sec-sec.

C 2 mi/hr-sec.

YOUR ANSWER --- C

This answer shows you have forgotten the definition of slope! The slope can't be the product of Δv and Δt. Slope is always the ratio of the change along the vertical axis to that along the horizontal axis. A ratio is a fraction, not a product.

Please return to page 121. In selecting the answer from the remaining two, be careful that you get the numerator and the denominator in the right order.

YOUR ANSWER --- D

Figure 17(4) on page 107 is not a correct single graph of distance vs. time for this trip; perhaps you thought two trips were involved.

Let us analyze it quickly.

Line 1: This is a good start. It shows the car's distance from the starting point increasing with time. So far, so good. But, what happens next?

Line 2: This shows the car returning to the starting point in zero time.

Line 3: This line along the t-axis tells us that the car is stationary at the starting point for quite some time. This doesn't agree with the description of the trip at all. Were you setting up a new starting point?

In order to finish the answer for this question, please go on to page 55.

Line 4: Perhaps you meant to show that, after returning to point A, this amount of time has elapsed. At first glance, it looks as if the car has moved from point A in a direction away from point B, and in zero time, at that.

Line 5: Here you must have started from point B at the new departure time, going back to point A. But, observe the axes. Distance is measured vertically on this graph. Actually, a d-t graph should be a continuous progression from left to right, covering all details of the entire trip. Another difficulty with this line is that either it has the wrong slope to show speed, or it doesn't end at the time the trip ended. That is, it doesn't show the total elapsed time.

Please return to page 107 and select another answer.

YOUR ANSWER --- B

You are correct. Describing the graphs in the simplest possible way, you might say that the curve for Car 1 goes up faster than the curve for Car 2 in equal time intervals.

If you remember your basic mathematics, you can see that the slope of the curve for Car 1 is greater (or steeper, if you like) than that for Car 2. A greater slope indicates a correspondingly greater speed because it shows positively that a greater distance is being covered per unit time. Slope means steepness. A vertical line has infinite slope; a horizontal line has zero slope.

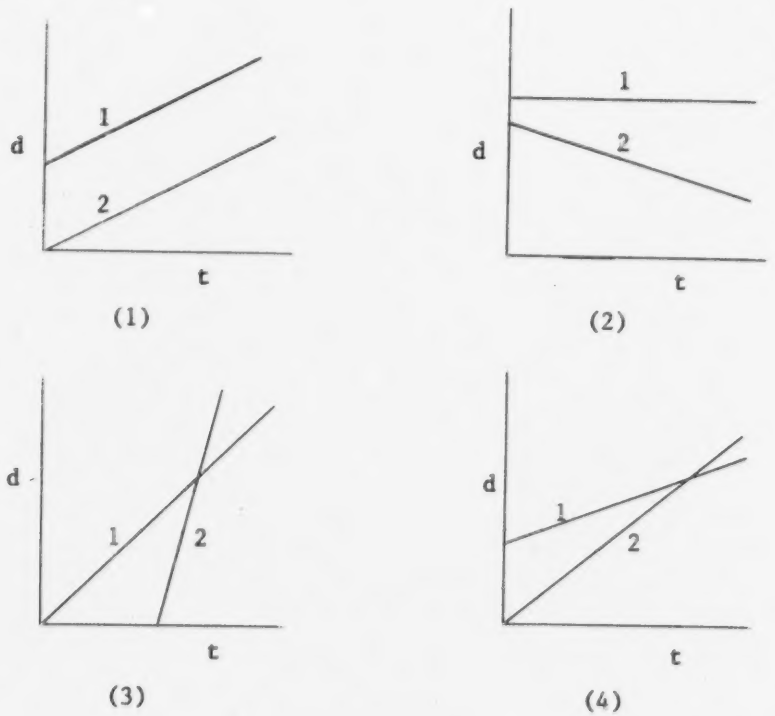


Figure 12

Study the four graphs in Figure 12. Which graph shows two objects moving with the same speed?

(16)

A Graph 4.

B Graph 3.

C Graph 2.

D Graph 1.

YOUR ANSWER --- B

This is incorrect. This answer expresses the distance the toy train would travel in 1 minute, not 10 minutes. You know there are 60 sec in 1 min. so you probably said:

$$d = 4 \text{ ft/sec} \times 60 \text{ sec/min}$$

Now, if you cancel the "sec" factors, you wind up with 240 ft/min or 240 ft traveled in <u>each minute</u>. But the toy train was permitted to run for 10 minutes, and therefore your solution is incomplete.

Please return to page 5 and select another answer.

YOUR ANSWER --- B

The heavy straight line is the curve of the motion. (Note that we use the word curve in its most general form. A straight line is merely a special case of what we normally call a curved line.) Using the graph in the normal way, we note that after 0.20 hr has passed, the speed is 35 mi/hr just as it was initially. At 0.40 hr, the speed is still 35 mi/hr. The same is true after the whole hour has gone by. That is, the curve neither rises nor falls but stays parallel to the X-axis.

How, then, would you describe a speed which did not change after any amount of time had passed within the limits of the graph?

Please return to page 86 and select another answer.

YOUR ANSWER --- C

Your decimal has wandered! You obviously used the relation d = vt to find the distance traveled, but in multiplying 35 mi/hr (v) by 0.60 hr (t), you did not position the decimal point properly.

Please return to page 6. Watch the decimal point in choosing your next answer.

YOUR ANSWER --- A

This answer is not right, but it indicates good thinking nevertheless. To come out with an answer of 30 miles you must have said something like this to yourself: "Why not take the average speed over the entire trip and multiply it by the time, rather than perform the same kind of operation twice for the two separate short trips?"

Well, let's see. During the first trip, the speed was 30 mi/hr; during the second trip, the speed was 50 mi/hr. The average of 30 and 50 is 40. Using 40 mi/hr as the average speed for the entire trip, you must then have substituted in d = vt and obtained:

$$d = 40 \text{ mi/hr} \times 0.75 \text{ hr} = 30 \text{ mi}$$

But, this answer is incorrect. You were clever to think of the average-speed short cut, however. Are you smart enough to figure out why this method will not work here?

Give it some thought. After you have answered the original question correctly, we'll analyze the error in reasoning in using the average speed in a problem of this type.

Now please return to page 33 and work out the answer in two steps.

YOUR ANSWER --- B

You are perfectly correct. Since the long test demonstrated that you had mastered a great deal of the course work and the short one showed that you had missed only a very small part, the long test should be given much more weight than the short one. Similarly, in the problem of distance covered in Figure 3 on page 33, more weight would have to be given to the velocity during the trip CD because it lasted a longer time. It would not be a terribly difficult job to calculate the average speed by properly weighting the two trip speeds, but it is not worth the trouble.

We have demonstrated that the area under a v-t curve represents the distance covered by the moving object. The usefulness of this concept is immediately apparent from Figure 3 on page 33. It enables you to answer the following question at a glance.

During which trip, AB or CD, was the greater distance covered?

(6)

A Trip AB.

B Trip CD.

CORRECT ANSWER: The time required for the object to travel 300 mi is 5 hr. The solution:

$$t = \frac{d}{v} = \frac{300 \text{ mi}}{60 \text{ mi/hr}} = 5 \text{ hr}$$

In most real life situations, it is virtually impossible for a moving object to maintain a constant speed. Even in the case of a controlled automobile, it normally starts from rest, picks up speed until it is going as fast as the driver desires, and then proceeds at constant speed for a limited time. Imagine a hypothetical situation starting with a car whose driver has just paid the toll as he enters a section of the New York Thruway. After paying the toll he allows the car to pick up speed uniformly until it reaches the speed limit of 60 mi/hr. With light traffic, the car can then maintain this speed for an indefinite interval.

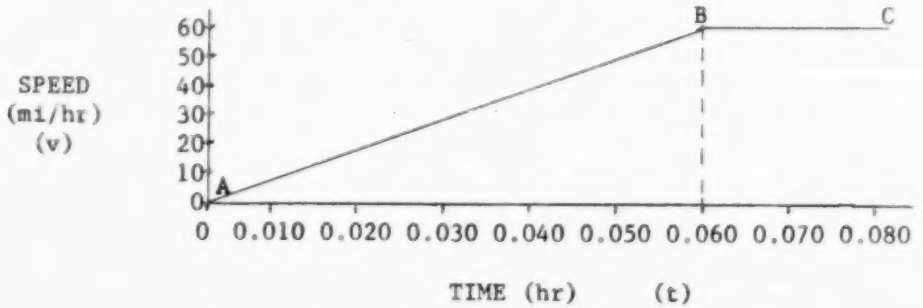


Figure 5

Figure 5 shows this entire situation graphically. In analyzing the graph, we must understand the meaning of each section. Study the graph carefully; then proceed to the question below.

Which one of the following statements is entirely true?

(7)

A AB shows a uniform speed while BC shows a uniform distance.

B AB shows a varying speed while BC shows a constant speed.

C The area under BC shows the distance the car covered after paying the toll.

CORRECT ANSWER: The average speed of the plane was 200 mi/hr.

You probably found this answer mentally in a second or two. What you actually did, whether or not you realize it, was to set up the ratio of distance to time:

$$\text{average speed} = \frac{\text{distance}}{\text{time}} = \frac{d}{t} = \frac{600 \text{ mi}}{3 \text{ hr}} = 200 \text{ mi/hr}$$

We use a special symbol for average speed. When you see the letter "v" with a bar over it like this: $\bar{v}$, read it out as "bar v" and remember that it means average speed. Rewriting the equation above to include this symbol, we have:

$$\bar{v} = \frac{d}{t}$$

Please turn to page 64 to continue.

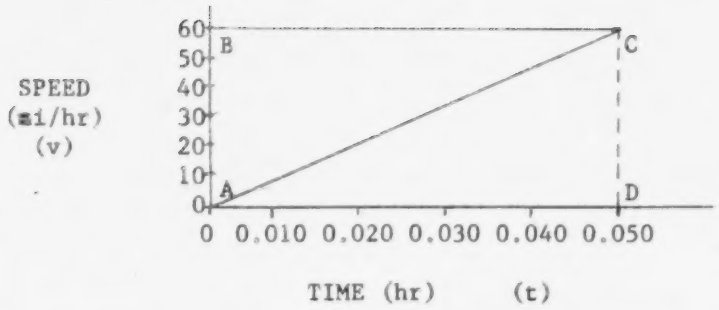


Figure 6

There is another good way to determine the average speed of an object that gains speed smoothly and uniformly. Refer to Figure 6. To find the distance covered by the car for the conditions described by curve AC we'll find the area under the curve. Since ACD is a right triangle, then CD is the altitude. Knowing that the area of a triangle is given by $A = \frac{1}{2}bh$, where b = base and h = altitude, we can at once determine the area of ACD as:

$$A = \frac{1}{2} \times 0.05 \times 60 = 1.5$$

Thus, the distance in this case is 1.5 miles.

Next, let us consider what distance would have been covered if the car had gone at a uniform speed of 60 mi/hr. This, of course, is the area of the rectangle ABCD in Figure 6, which turns out to be: $A = 0.05 \times 60 = 3.0$ miles.

This is what we have:

Speed	Time	Distance
(1) rises from 0 to 60 mi/hr	0.05 hr	1.5 mi
(2) constant at 60 mi/hr	0.05 hr	3.0 mi

So, for a body that starts from rest and increases its speed uniformly and smoothly, which of the statements below is correct?

(8)

A Its average speed is equal to half its final speed.

B Its average speed is double its final speed.

C Its average speed is not definitely related to its final speed.

YOUR ANSWER --- B

The second part of the statement you chose for your answer does not follow from the first. Sure, his displacement is zero, but the expression $\bar{v} = v/2$ does not depend upon the displacement.

It is quite possible under the correct circumstances, to determine the average speed of a moving object using $\bar{v} = v/2$, even if the displacement at the end of the measured time interval is zero.

Thus, the displacement may be zero but this is not why the expression $\bar{v} = v/2$ cannot be used to find the average speed.

What do we know about the final speed, and the manner in which speed changes in this problem?

Please return to page 92 and select another answer.

CORRECT ANSWER: The diagrams which show the body starting from rest are (B), (C), and (D).

If a body starts from rest, then at zero time its velocity is zero. In any normal graph, the origin of the X- and Y-axes represents the 0-0 coordinate, as you know.

Thus, to determine whether or not a body starts from rest, look for a v-t curve that passes through the origin. This is true of (B), (C), and (D) although these three graphs show very different kinds of motion.

Graphs (A) and (E) of Figure 7 on page 11 show that the body started with some initial velocity other than zero. In which one does the body have the greater initial velocity?

Write your answer; then turn to page 93 to check it.

YOUR ANSWER --- A

When you say that a body "maintains a constant speed," you mean that the speed does not change from minute to minute. The best way to tell from a v-t graph whether or not this condition holds is to observe the slope or slant of the curve. If the curve is straight and perfectly horizontal, then the points being plotted remain at the same Y- coordinate value (vertical height throughout the interval of the graph). Such a curve has a slope of zero. This in turn tells you that, as time passes (to the right along the X-axis), the speed does not go up or down.

Hence, in a v-t graph, constant speed is indicated by a curve that is perfectly horizontal (has a zero slope).

Please return to page 39 and select another answer.

YOUR ANSWER --- C

No. Once a conventional way of expressing something is accepted by workers in a given field, it is customary for everyone writing or talking in this field to observe the same conventions.

Every textbook in physics adheres to the "Δ" convention. This symbol means an interval or a change in a physical quantity. If you want to talk about some specific time, you might say or write t_b. But, if you are referring to a change in time or an interval of time, you must use the "Δ" sign.

Please return to page 13 and select another answer.

YOUR ANSWER --- B

This statement is untrue. We do not have times or speeds that are identified by the subscript "a" or "b." We have only used these subscripts along with the sign "Δ" to identify the interval or change in the two variables, time and speed.

Since the "Δ" is omitted, the equalities above say that the speed at "b" is equal to the speed at "a," when the time at "b" is the same as at "a." But the time at "a" is an interval, designated "Δt."

Please return to page 46 and select the correct answer.

YOUR ANSWER --- B

You are correct. In curved-line v-t graphs, equal time intervals do not correspond to equal changes in speed.

The ideas we have presented are worth noting.

NOTEBOOK ENTRY

(Item 2)

(d) When a v-t graph is a curved line, this signifies that the body is gaining or losing speed non-uniformly. In other words, the curved line tells you that, for equal time intervals, the changes in speed are not equal to each other. Copy Figure 9 on page 41 as an example.

Notebook Check

Refer to Lesson 5, item 1(d). What does this item say?

(14)

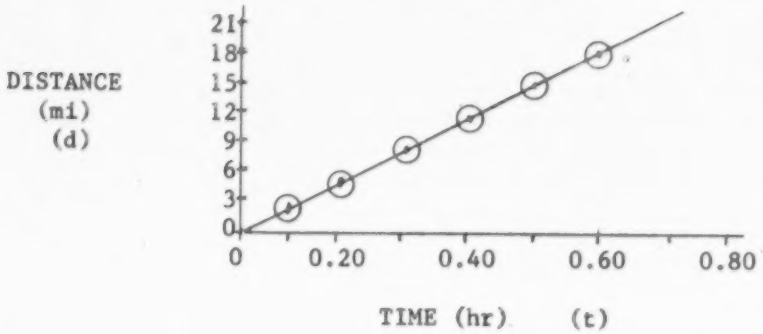
A Item 1(d) states the meaning of the area under a v-t curve.

B Item 1(d) defines speed and gives conventional units for speed.

C Item 1(d) gives the relationship between d, v, and t.

D Item 1(d) gives two other forms of the relation d = vt.

THE CORRECT GRAPH appears below in Figure 10.



t (hr)	d (mi)
0.10	3
0.20	6
0.30	9
0.40	12
0.50	15
0.60	18

Figure 10

Like graphs of all direct proportions, this d-t curve is a straight line. It shows that equal distances are covered in equal times.

Take any time interval on the X-axis, say, from 0.20 hr to 0.30 hr and call this Δt_a. Now take any other equal time interval, say from 0.50 hr to 0.60 hr and designate this as Δt_b. Drawing the interval bounding lines and their horizontal projections (exactly as we did for the v-t graph), we find that the distance covered in Δt_a is 9 mi - 6 mi = 3 mi, and that the distance covered in Δt_b is 18 mi - 15 mi = 3 mi. Any other similar selections of time intervals will show the same thing. Thus, for constant speed, if $\Delta t_a = \Delta t_b$, then $\Delta d_a = \Delta d_b$.

Now, keeping in mind the meanings of the axes and their divisions, analyze Figure 11, which shows, graphically, the motion of two cars on the same set of axes. What do these graphs tell you about the difference in the two motions?

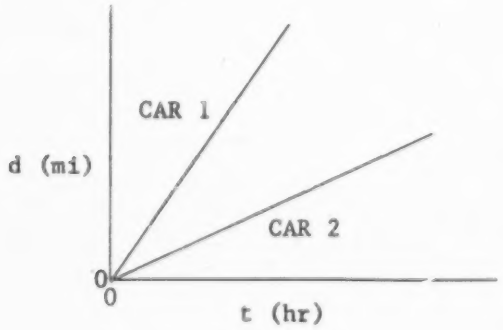


Figure 11

(15)

A Car 1 has started moving sooner than Car 2.

B Car 1 has a higher speed than Car 2.

C Car 1 moves with uniform speed, but Car 2 moves with non-uniform speed.

D Car 2 has a higher speed than Car 1.

YOUR ANSWER --- C

This answer is incorrect. Curve 1 is parallel to the t-axis. As you will see in a short while, this means that its speed is zero. On the other hand, curve 2 is descending as it moves to the right, indicating that the object is "returning home," so to speak.

In any case, the two curves have different slopes; hence they cannot represent bodies traveling with the same speed.

Please return to page 56 and select another answer.

YOUR ANSWER --- C

We have been assuming that you know the meaning of the word "ratio." You probably do, but became careless in reading this item.

We define slope as the ratio of the distance "up" the d-axis to the distance "along" the t-axis. This implies that you are to set up a fraction consisting of the "up" distance in the numerator and the "along" distance in the denominator. Since the answer you selected is a product rather than a quotient, it could not possibly define any ratio.

Please return to page 98 and look over the other answers carefully before you make your selection.

YOUR ANSWER --- A

You're not being careful with the decimal point. Recalling that the speed of a moving body may be determined from the slope of its d-t curve, you first write: slope = $\Delta d/\Delta t$. Then, substituting the known values for car A, you have:

$$\text{speed} = \text{slope} = \frac{\Delta d}{\Delta t} = \frac{6 \text{ mi}}{0.1 \text{ hr}}$$

Now, if you watch that decimal point, you'll come out with the right answer.

Please return to page 17 and select the correct answer.

YOUR ANSWER --- B

This answer is incorrect. The only way you could have arrived at this answer is by misreading the distance or by committing an error in arithmetic.

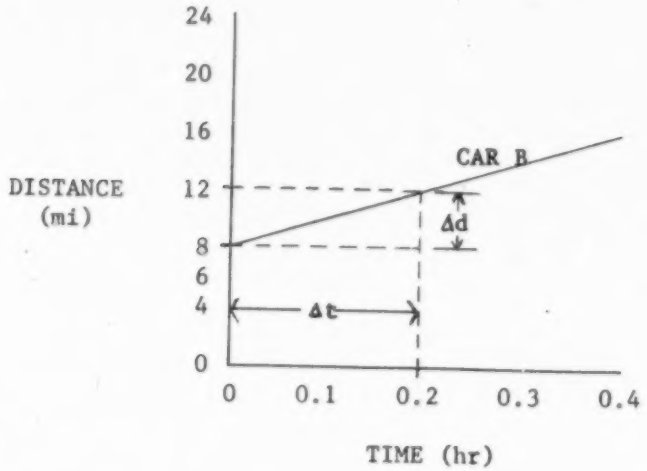


Figure 15

We have duplicated the curve for car B in Figure 15. The time interval chosen is 0.2 hr as shown. The change in distance is the difference between the starting point (8 mi from the zero point) and the position at the end of t.

You should be able to solve the problem now.

Please return to page 45 and select another answer.

YOUR ANSWER --- A

This answer is incorrect. You're working with the wrong car!

If the question had been, "How far was the slower car able to go before the faster car caught up with it?" the answer you chose would have been correct.

You probably realized that the intersection of the two curves marks the point where both cars have traveled the same distance from the origin during the measured time interval, so that this would be the location where car A caught up with car B. And it is also true that the slower car, car B, went a total distance of only 4 miles from its starting point when the meeting occurred. But this was not the question.

Therefore, please return to page 106, reread the question, and select the right answer.

YOUR ANSWER --- A

It is true that we might label the vector symbols "a" and "b" to distinguish between them, but these subscripts do not indicate "opposite-ness" of direction. It's O.K. for graphing, but we wanted a way to use vectors arithmetically.

Perhaps your memory may be triggered by reminding you that a pair of oppositely directed vectors are added <u>algebraically</u> to find their resultant. Does this help?

Please return to page 49 and select the correct answer.

YOUR ANSWER --- B

You are correct. Refer to Figure 17(2) on page 107. Line 1 describes the outgoing trip of 6 mi in 0.2 hr. Line 2 tells us that the car remained at rest for an interval of 0.25 hr while the driver concluded his business. Line 3 describes the return trip. Since it took a longer time (0.35 hr), the car was going more slowly than on the outgoing trip. Hence, the slope of line 3 is not as steep as that of line 1, and is negative because it is descending rather than climbing. All this means, of course, is that the car is approaching rather than moving away from the starting point.

So, you see, we have chosen the change of displacement of the car as (+) if it was moving toward the right (Figure 16 on page 107) and as (-) if it was moving toward the left. Stated in other terms, if the distance between the starting position and the car is increasing, then d is (+); if the distance is decreasing, then d is (-).

We shall clarify the concept of graphical representation of positive and negative displacements with the help of additional illustrations.

Please go on to page 79.

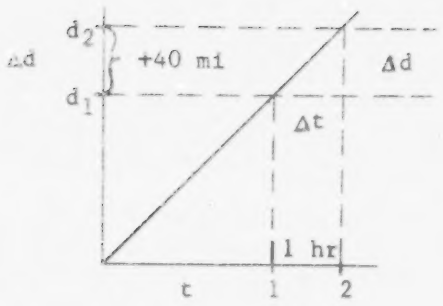


Figure 18

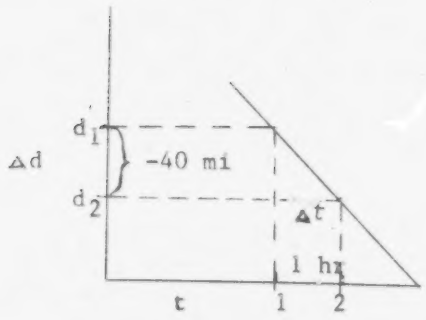


Figure 19

In Figure 18, t_2 is a later instant in time than t_1; hence $\Delta t = t_2 - t_1 = 1$ hour. During the interval Δt, the moving body (a car) covers the distance $d_2 - d_1 = 40$ mi. The position d_1 is associated with time t_1; similarly, the position d_2 is associated with time t_2. Since d_2 is a larger number than d_1, then $d_2 - d_1$ = a positive quantity. Thus, both Δt and Δd are positive quantity since slope = $\Delta d/\Delta t$ = +40 mi/+1 hr = +40 mi/hr. This leads to a simple convention or agreement: the slope of a d-t curve is positive if the curve climbs with increasing time.

The reverse condition is shown in Figure 19. The time interval is again t = +1 hr. (We use the plus sign here only to show that t_2 is larger than t_1, so that $t_2 - t_1$ must be (+).) Again, d_1 is associated with t_1, and d_2 with t_2. This time, however, d_1 is farther from the starting point; hence d_1 is a larger number, making $d_2 - d_1$ come out negative. If d is negative and t is positive, then what is the speed of the car in the case of Figure 19?

(23)

A 40 mi/hr.

B -40 mi/hr.

YOUR ANSWER --- C

The minus sign, as in v = -20 km/hr, does not indicate a changing speed. It is perfectly possible for a straight-line d-t graph to have a negative slope, yet such a graph describes motion with constant speed because it is a straight line.

The use of algebraic signs with quantities such as distance and speed symbolizes changed direction, nothing more.

Please return to page 23 and select the correct answer.

YOUR ANSWER --- C

Your thinking was good, but you didn't watch all the units. If the final speed of the cart is given in ft/sec and the time of travel is given in seconds, how can you possibly come out with an acceleration in miles per hour per second? You can't, of course.

Please return to page 52 and select another answer.

YOUR ANSWER --- B

You've inverted the ratio. Slope is always the ratio of the change along the vertical or Y-axis to the change along the horizontal or X-axis. Thus, the general formula for slope is always: slope = $\Delta y/\Delta x$.

Please return to page 121 and select the right answer.

YOUR ANSWER --- D

No! This idea is not contained in item 1(d). Your notes aren't in the best of conditions, so do a better job of copying this time.

Please turn to page 48.

This page has been inserted to maintain continuity of text. It is not intended to convey lesson information.

YOUR ANSWER --- C

To obtain this answer, you must have been confused by the units. You must have done it this way:

$$d = \tfrac{1}{4} \text{ sec/ft} \times 60 \text{ sec/min} \times 10 \text{ min}$$

Numerically, this turns out to be 150. But look at your units. When you invert the first factor, you must also invert the unit for speed. Then, working out the units you see that the result is 150 sec^2/ft. This doesn't mean much. Instead of multiplying, you divided the 60 sec/min factor by 4 ft/sec.

Now try multiplying the three terms, numerically and with units. You should come out with the right answer.

Please return to page 5 and select another answer.

CORRECT ANSWER: It takes the automobile 3 hr to travel 180 km at a speed of 60 km/hr.

The solution: $t = \frac{d}{v} = \frac{180 \text{ km}}{60 \text{ km/hr}} = 3 \text{ hr.}$

Simple enough, isn't it? You can do this next one mentally. What must be the speed of a car that makes a 90 mi trip in 3 hours? The answer is, of course, 30 mi/hr. The formal solution is:

$$v = \frac{d}{t} = \frac{90 \text{ mi}}{3 \text{ hr}} = 30 \text{ mi/hr}$$

All this has been more or less in the nature of a review. Our next venture may be new to you.

However, before continuing, please turn to page 128 in the blue appendix.

It is often very helpful to use a graph to analyze motions. Let us examine the graph in Figure 1 carefully. The horizontal or X-axis is the time t; the vertical or Y-axis is the speed v. Such a represenation shows the relationship between v and t and is often referred to as a v-t graph. (The symbol (-) in v-t is not a minus sign; it merely separates the two factors.) Study the graph in view of the statements below, and select the correct one.

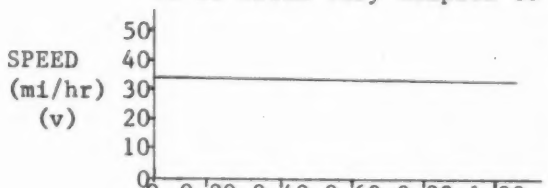


Figure 1

(2)

A Figure 1 graphs the motion of something undergoing a decrease in speed as time passes.

B Figure 1 graphs the motion of something undergoing an increase in speed as time passes.

C Figure 1 graphs the motion of something moving with constant speed.

YOUR ANSWER --- B

You are correct. The solution is:

$$d = vt = 35 \text{ mi/hr} \times 0.60 \text{ hr} = 21 \text{ mi.}$$

Let us examine the rectangle formed by the v-t curve (heavy line) and the broken vertical line that measures the height of the curve from the X-axis in Figure 2 on page 6. A graph is actually a scale drawing, but the vertical and horizontal scales are not the same. Actually, on the speed axis the scale is 1 cm = 23 mi/hr, but on the time axis the scale is 1 cm = 0.213 hr. This makes no real difference, however, so long as we think in terms of the quantities actually being represented by the scale drawing. In other words, in speaking about the height of this curve, we say that it is 35 mi/hr high. If we said it was 3.5 cm high, this would mean nothing since we would still have to translate this into mi/hr by means of the scale.

Thus, measuring the height of the curve in mi/hr and the length of the rectangle in hr, what is the area under the curve?

Write your answer, then check it by turning to page 32.

YOUR ANSWER --- B

You are correct. In the first trip, from A to B, the car travels at a speed of 30 mi/hr for 0.25 hr. hence: d = vt = 30 mi/hr x 0.25 hr = 7.5 mi. In the second trip, from C to D, the car goes 50 mi/hr for 0.50 hr. so we have: d = vt = 50 mi/hr x 0.50 hr = 25 mi. The entire trip, then, covers 7.5 mi + 25 mi, or 32.5 mi.

It sometimes occurs to students that a short cut is possible. They reason, "If the first trip is at 30 mi/hr and the second trip is at 50 mi/hr, then the average speed of the car was 40 mi/hr for the total trip. So why not solve the problem in a single step by substituting the average speed, 40 mi/hr, and the total time, 0.75 hr in d = vt?". If you do this, you find that the answer comes out to be 30 mi.

This answer is wrong. But why is it wrong? We'll use a more familiar example to show you why.

Suppose your teacher gave you only two tests during a given marking period in school. The first was a full-period test of, say, 45 minutes on which you received a grade of 95%. The second tests was a 5-minute quiz on which you earned a grade of (horrors!) 35%. The average of 95% and 35% is 70%. Would your teacher be justified in giving you a report card mark of 70% for the marking period?

(5)

A Yes.

B No.

YOUR ANSWER --- A

If the area under a curve represents the distance covered, then this answer cannot be right. Doesn't a mere glance at the diagram in Figure 3 on page 33 tell you that the area under AB is <u>smaller</u> than the area under CD?

Please return to page 61 and select the correct answer.

YOUR ANSWER --- C

There's a misunderstanding here. The toll was paid at "zero time." That is, at the time when the car was at rest (point A). After that, the automobile went into motion, gaining speed until it reached 60 mi/hr (point B). Therefore, throughout the interval from A to B, distance was being covered.

If you determined the area under BC alone, as your answer indicates, you would only find the distance covered by the car after it reached its maximum speed. You would be neglecting completely the distance covered by the car between zero time and 0.060 hr.

Please return to page 62 and select another answer.

YOUR ANSWER --- B

That's not right. If a body starts from rest, then at the instant of starting its velocity must be zero. At the end of the interval during which it picks up speed, it is moving at its final speed. The average speed, then, must be somewhere between zero and its final speed.

In thinking this out, you must bear in mind that at no time during the interval under discussion does the body slow down. Hence, its final speed must be greater than the speed was during any other part of the interval. Averaging this out must give you a lesser speed than the final one.

Please return to page 64 and select another answer.

CORRECT ANSWER: The motorcyclist must maintain an average speed of 68.8 mi/hr to qualify in the test heat.

In running the heat, the motorcyclist starts from rest and covers a distance of 12.4 mi/lap x 10 laps = 124 mi. If he does this in 1.8 hr, then his average speed is:

$$\bar{v} = \frac{d}{t} = \frac{124 \text{ mi}}{1.8 \text{ hr}}$$

$$\bar{v} = 68.8 \text{ mi/hr}$$

Which of the statements below is the best explanation of why you could not figure his average speed from the expression $\bar{v} = v/2$?

(9)

A To use this expression, you must know his final speed, v. This is not given in the problem.

B Since, at the end of 10 laps, the motorcyclist returns to his starting point, his displacement = 0; hence you cannot use $\bar{v} = v/2$ to determine average speed.

C The expression $\bar{v} = v/2$ may be used only when the moving body picks up speed uniformly. Since the motorcyclist's speed rises and falls irregularly, the equation is not applicable.

CORRECT ANSWER: Diagram (E) indicates a higher initial velocity because the Y- coordinate at zero time is greater in this diagram than in (A).

Which one of the diagrams in Figure 7 on page 11 shows that the body is gaining and losing speed alternately during its trip?

Write your answer; then turn to page 39 to check it.

YOUR ANSWER --- B

Incorrect. In diagram (c) of Figure 7 on page 11, we have, for the first time, a v-t curve that is really curved. In our original discussion of the v-t curve, we pointed out that when uniformly changing speed is plotted on a graph, the result is always a straight line. In some cases, as in diagram (C), the v-t curve bends upward or downward very smoothly as time passes. It should be evident that if uniformly changing speed gives a straight line, then it cannot also give a curved line.

If this sounds like double-talk at this point, don't despair. It will all be clear when we analyze Figure 7(C) in greater detail.

Meanwhile, return to page 39. You should have no trouble in making the right choice now.

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YOUR ANSWER --- D

All right, we'll try another example to clear this up. Refer to Figure 8A.

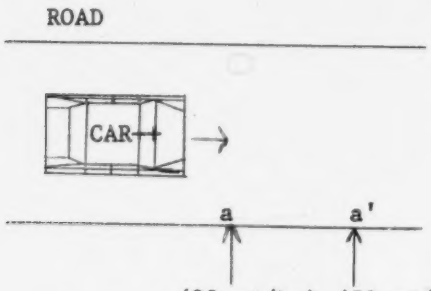

Figure 8A

You are driving the car. You start from rest in the initial position shown, with your foot all the way down on the accelerator pedal. As you pass the first observer at position a, he clocks your speed and finds that you are doing 20 mi/hr. As you reach observer a' (a prime), your speed has increased so that the observer at a' clocks you at 50 mi/hr.

Now we want to express your gain of speed between a and a'. There are several good ways of doing it. For instance, you might say: The gain of speed was the difference between 50 mi/hr and 20 mi/hr; hence it was a gain of 30 mi/hr.

This is correct but it requires too many words. You can say the same thing briefly, in this simple fashion:

$$v_{a'} - v_a = 30 \text{ mi/hr}$$

Without writing another word, you have told your listener that the change in speed was 30 mi/hr.

Finally, you might say it even more briefly like this:

$$\Delta v_a = 30 \text{ mi/hr}$$

Here, the "Δ" tells your listener that you are stating a change in speed, and that the change was 30 mi/hr. You have used the subscript "a" to identify the interval between the two observers, that's all.

Please return to page 13 and select the correct answer.

YOUR ANSWER --- A

Not quite. We can account for this error in only one way: You are not translating the symbols into words to help you understand what they mean. The statement in your answer should be translated this way: "In a curved-line v-t graph, a change in speed over any time interval will be the same as the change in speed over any other EQUAL time interval."

Aren't the two time intervals, Δt_a and Δt_b, equal to each other? We have said that they are. But look at the corresponding speed changes, Δv_a and Δv_b in Figure 9 on page 41. Are these equal to each other? Of course they aren't.

It should be readily seen that in a curved-line v-t graph, the changes in speed of the moving body for two equal time intervals are <u>different from each other</u>.

Please return to page 41 and select the correct answer.

YOUR ANSWER --- D

You are correct. Speed is shown by the slope of the d-t curve. Both curves have the same slope; hence they represent objects moving with the same speed.

At this point we need a rigorous definition of the word slope. Once the word is defined, you will immediately recognize why the slope of a d-t curve tells you the speed of the moving body.

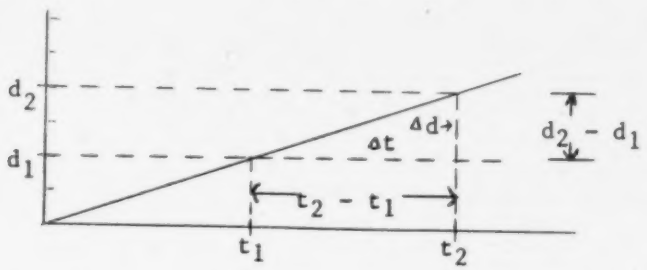

Figure 13

Refer to Figure 13. The interval of time that we have pointed out on this d-t graph is $t_2 - t_1$, or Δt. Now, during the interval Δt, the speed of the moving body remains constant but it travels the distance from d_1 to d_2. The change of distance is, therefore, $d_2 - d_1$ or Δd. Since slope means steepness of climb, we can define the slope as the ratio of the distance "up" to the distance "along" the time axis. Since the distance "up" is Δd and the distance "along" the time axis is Δt, which one of the following defines the slope?

(17)

A slope = $\frac{\Delta d}{\Delta t}$.

B slope = $\frac{\Delta t}{\Delta d}$.

C slope = $\Delta d \times \Delta t$.

YOUR ANSWER --- C

There are two ways to determine the speed of a moving body from its d-t curve.

First, take it from the basic point of view. Refer to Figure 14 on page 17 and look at the graph for car A. Starting at zero time, the origin of the axes, imagine that we let it travel for exactly 0.1 hr. During this time, the graph shows the distance moved to be exactly 6 mi. (Note the coordinates of the point where the two broken lines intersect on the curve. They are 0.1 hr, 6 mi.) So, if car A can move 6 mi in 1/10 of an hour, how far will it move in one whole hour? Ten times as far, of course. Hence, it will move 60 miles in one hour. Its speed is therefore 60 mi/hr.

The second way to view this is in terms of slope. Slope is defined as the distance "up" along the d-axis <u>over</u> the distance "along" the t-axis; that is, $\Delta d/\Delta t$. Substituting any arbitrary value of <u>Δt</u> and the <u>corresponding</u> value of <u>Δd</u>, we might write:

$$\text{speed} = \text{slope} = \frac{\Delta d}{\Delta t} = \frac{6 \text{ miles}}{0.1 \text{ hour}} = 60 \text{ mi/hr}$$

We hope this clears it up for you. To check , can you find the speed of an airplane that travels 35 miles in 0.1 hr? Write your answer, obtained by the slope method preferably, and then turn to page 100.

CORRECT ANSWER: The speed of the plane is 350 mi/hr.

As we suggested, the slope method should be used. For this example, $\Delta d = 35$ mi because this is the change of distance from a starting point traveled by the plane in the time interval $\Delta t = 0.1$ hr.

Now:

$$\text{speed} = \text{slope} = \frac{\Delta d}{\Delta t} = \frac{35 \text{ mi}}{0.1 \text{ hr}} = 350 \text{ mi/hr}$$

Try another. A d-t curve representing a boy walking along a straight street with uniform speed rises 12 ft along the d-axis for every 4 sec along the t-axis. What is the speed of the boy?

Write your answer; then turn to page 101 to check it.

CORRECT ANSWER: The speed of the boy is 3 ft/sec.

If the d-t curve rises 12 ft along the d-axis in the selected time interval, then $\Delta d = 12$ ft. The corresponding time interval is given as 4 sec, hence $\Delta t = 4$ sec.

$$\text{speed} = \text{slope} = \frac{\Delta d}{\Delta t} = \frac{12 \text{ ft}}{4 \text{ sec}} = 3 \text{ ft/sec}$$

It's really not very difficult, is it? To determine the speed of a body moving at a uniform rate, take any convenient value of Δd, establish the corresponding value of Δt; then obtain the slope from the above relation. This is the speed of the body.

Now try the original problem. Please return to page 17.

YOUR ANSWER --- C

This is not item 1(d). Your notes aren't in good order. We'll give them to you again, so copy them carefully.

Please turn to page 48.

This page has been inserted to maintain continuity of text. It is not intended to convey lesson information.

YOUR ANSWER --- D

This is not correct. The curve of Car 2 has been extended farther in time, not distance. Actually the distance it has covered is less than that traveled by Car 1. At any given time, Car 1 has gone a greater distance than Car 2. What does this mean in regard to relative speed of the two cars?

Please return to page 71 and select another answer.

YOUR ANSWER --- C

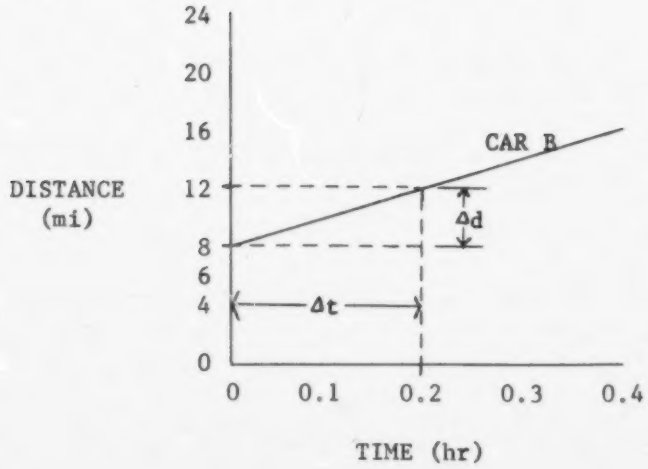

Figure 15

Figure 15 is a duplicate of the previous figure except that we have omitted the curve for car A to make it a bit simpler. We have arbitrarily selected an interval of 0.2 hr as Δt, although we could have chosen any other.

To get an answer of 60 mi/hr you must have made a mistake based on the fact that the curve for car B does not go through the origin. The vertical broken line from the 0.2 hr mark intersects the curve opposite the 12 mi mark. If you then assumed that the d for 0.2 hr was 12 mi, you would derive a slope of:

$$\frac{\Delta d}{\Delta t} = \frac{12 \text{ mi}}{0.2 \text{ hr}} = 60 \text{ mi/hr}$$

But Δd can't be 12 mi! The car started from a point 8 mi from the origin in the first place. This means that the distance it covered over the 0.2 hr interval was 12 mi - 8 mi = 4 mi.

This makes a big difference in the slope, doesn't it?

Please return to page 45 and select another answer.

CORRECT ANSWER: Car B was 8 mi farther along the road than Car A at the start of the timing.

This is shown by the fact that at zero time car B was already at a point 8 mi ahead of the zero point (origin) where car A started.

We can extract another important point of information from the set of graphs of Figure 14 on page 17.

How far did the faster car have to travel to catch up with the slower car?

(20)

A 4 mi.

B 8 mi.

C 12 mi.

YOUR ANSWER --- B

You are correct. Now we shall apply the same convention to the analysis of the picture given in Figure 16. This gives the details of a complete trip made by a car. Our driver leaves point A and journeys 6 mi to point B, making the trip in 0.2 hr. He stops at B and stays there for 0.25 hr while he completes his business. He then returns to point A along the same road, taking 0.35 hr for the trip on the way back.

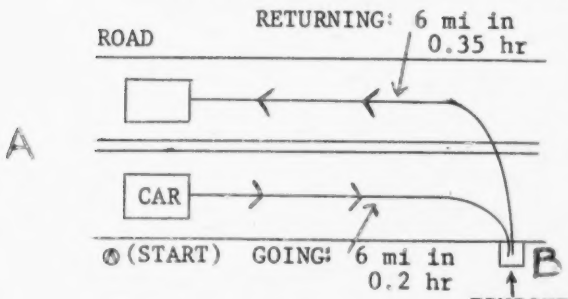

Figure 16

Study the four graphs in Figure 17 very carefully. Only one of these is a correct graphical representation of the complete trip. Which one is it?

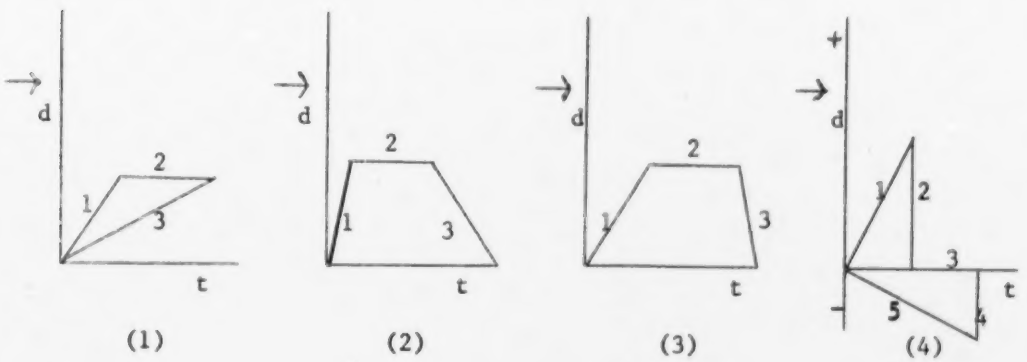

Figure 17

The correct graphical representation is given by

(22)

A Diagram (1).

B Diagram (2).

C Diagram (3).

D Diagram (4).

YOUR ANSWER --- A

The sign of this answer is incorrect. Since speed = slope and:

$$\text{slope} = \frac{\Delta d}{\Delta t} = \frac{-40 \text{ mi}}{+1 \text{ hr}},$$

then what must the sign of the velocity be?

Please return to page 79 and select the other answer.

YOUR ANSWER --- A

You failed to take into account the fact that the car had an initial velocity of 20 mi/hr when the acceleration period started. In other words, Δv is <u>not</u> 60 mi/hr.

Figure out the correct value for Δv. Then please return to page 26 and select another answer.

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YOUR ANSWER --- C

You are correct. The solution follows from the definition of acceleration:

$$a = \frac{\Delta v}{\Delta t} = \frac{60 \text{ mi/hr} - 20 \text{ mi/hr}}{6 \text{ sec}} = \frac{40 \text{ mi/hr}}{6 \text{ sec}} = 6.7 \frac{\text{mi}}{\text{hr-sec}}$$

That is, the car picks up an added speed of 6.7 mi/hr for every second it travels.

Please turn to page 132 in the blue appendix.

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YOUR ANSWER --- D

The numerical work is right, but you missed the units. This answer is incorrect. Did you notice that the car accelerated from 20 mi/hr in 6 seconds, not 6 hours?

Please return to page 26 and select the right answer.

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YOUR ANSWER --- B

You are correct. Algebraic signs applied to quantities such as distance and speed are directional signs only.

The remainder of this lesson will be devoted to the idea of acceleration (ak sell uh ray shun).

Perhaps you have read in popular magazines about the way new cars are test-driven. One of the most important tests is the determination of the time required for the car to reach, say, 60 mi/hr starting from rest. Suppose the test-driver observes that 10 sec are needed for the car to increase its speed from 0 mi/hr to 60 mi/hr. The graph in Figure 20 is the v-t curve for this situation. For convenience, we assume a straight-line graph showing a uniform increase of velocity throughout the 10-sec interval.

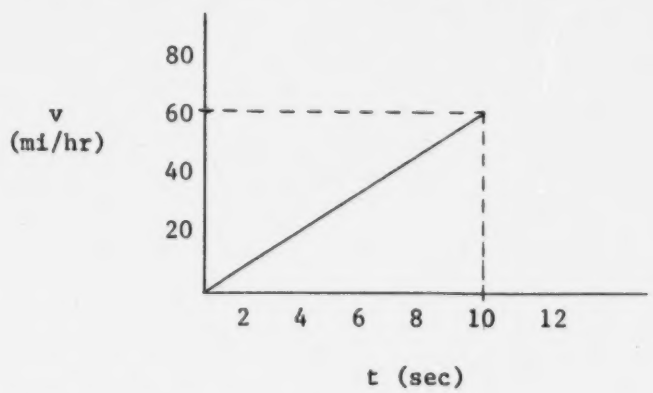

Figure 20

Since the car gains 60 mi/hr in 10 sec, how much speed does it pick up in each second?

Write your answer; then turn to page 52.

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YOUR ANSWER --- A

You are correct. This answer is the result of ordinary logic. If the cart accelerates uniformly, that is, if it picks up equal increments of speed in equal intervals of time, then if it increases from 0 ft/sec to 8 ft/sec in 4 sec, it must have picked up 2 ft/sec during <u>each</u> second.

You will notice at once that the denominator of the unit is a product of sec x sec. This may be, and usually is, written as <u>sec^2</u>. So, when we have an acceleration in which both time units are the same, as in this example, we generally use the squared form. The answer above might then be written 2 ft/sec^2, but it should still be read as "Two feet per second per second."

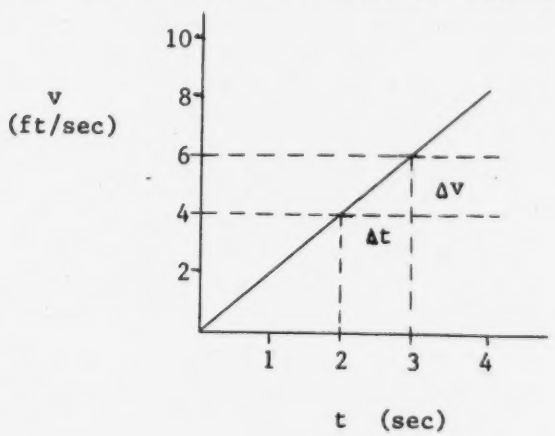

Figure 21

The v-t graph of the cart's motion is illustrated in Figure 21. The very end of the curve shows a speed of 8 ft/sec for a time of 4 sec, so we know that this graph adequately describes the motion. Also, we have arbitrarily selected a time interval Δt of 1 sec and have noted, in the usual manner, what the corresponding value of Δv is. (Note: we don't <u>have</u> to use a 1 sec interval; it just happens to be convenient on this graph.)

Which one of the following correctly describes the slope?

(26)

A slope = $\Delta v / \Delta t$.

B slope = $\Delta t / \Delta v$.

C slope = $\Delta v \Delta t$.

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YOUR ANSWER --- B

There are two errors in this answer.

First, the units are wrong. The car accelerated from 20 mi/hr to 60 mi/hr in 6 seconds, not 6 hours.

Second, you failed to take into account the fact that the car had an initial velocity of 20 mi/hr when the acceleration period started. In other words, Δv is <u>not</u> 60 mi/hr.

Please return to page 26 and select another answer.

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WORKSHEET

Please listen to Tape Segment 1 of Lesson 5 before answering the questions below. These answers should be selected by punching them out on the AV Computer Card. There are no DATA ITEMS for this Worksheet.

1. According to an important physical law which you will soon study, the acceleration of an object is directly proportional to the force applied to it provided that the mass of the body does not change. A graph of this relationship would have

   A force laid out on the x-axis.
   B force laid out on the y-axis.
   C acceleration laid out on the x-axis.
   D mass laid out on the x-axis.
   E mass laid out on the y-axis.

2. As an object falls freely in a vacuum, it gains kinetic energy. At any instant in its fall, the amount of kinetic energy it possesses is given by the equation:

$$K.E. = \frac{1}{2} m v^2$$

   in which K.E. is the kinetic energy, m is the mass of the falling body, and v is its velocity at the instant when its kinetic energy is to be determined. To observe graphically how energy varies with velocity, it would be best to plan the graph for a specific body

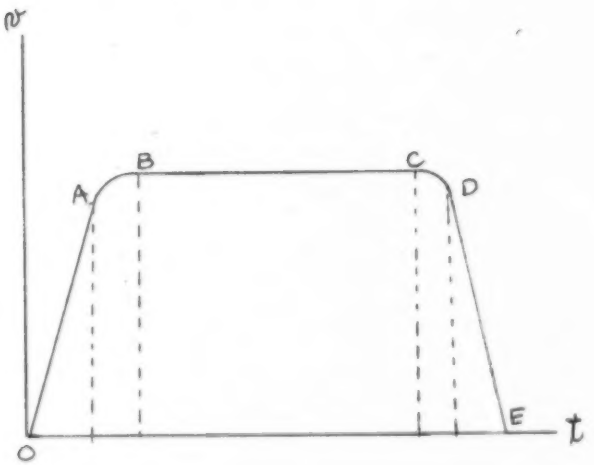
   A with mass units on the x-axis and energy units on the y-axis.
   B so that the square of the velocity is the independent variable.
   C so that the graph turns out to be a straight line.
   D with units for K.E. on the y-axis and units for v on the x-axis.
   E so that the mass of the body is shown as the independent variable.

You may now return to page 86
of the STUDY GUIDE and
continue with the program.

WORKSHEET

Please listen to Tape Segment 2 of Lesson 5 before starting this Worksheet. Continue to answer on AV Computer Card as before.

DATA ITEM A: The diagram below.



Select one and only one of the following items as an answer for each of the questions below.

A uniformly increasing speed.
B non-uniformly increasing speed.
C constant speed.
D uniformly decreasing speed.
E non-uniformly decreasing speed.

3. The line segment BC shows _____.

4. The line segment OA shows _____.

5. The line segment AB shows _____.

6. The line segment CD shows _____.

7. The line segment DE shows _____.

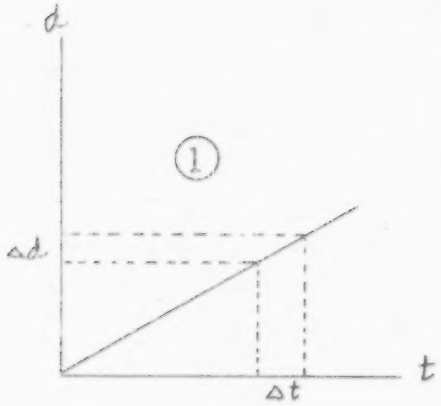
8. During the longest single interval of time shown on the graph, the object moved with _____.

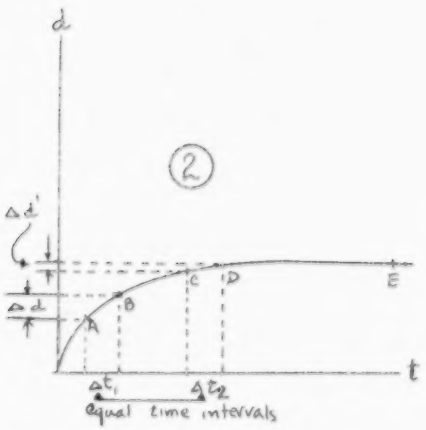
You may now return to page 38 of the STUDY GUIDE and continue with the program.

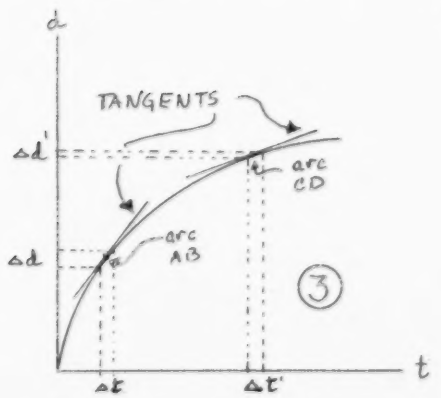
WORKSHEET

Please listen to Tape Segment 3 of Lesson 5 before starting this Worksheet. Use AV Computer Card as before.

DATA ITEM A: The diagrams shown below.







QUESTIONS

9. Refer to Diagram 2. From point D to point E, the speed of the object is very nearly

A constant
B zero
C equal to the speed at B
D equal to the speed at A
E equal to the speed at C

10. The speed of the moving object as graphed in Diagram 2 is

A least over the time interval Δt_1.
B smaller over the interval Δt_1 than over Δt_2.
C largest over the interval Δt_2.
D constant over the length of the entire curve.
E larger over the interval Δt_1 than over Δt_2.

11. Refer to Diagram 3. The tangent to the curve (two are shown) at a given point shows <u>by its slope</u>

A average speed at that point.
B instantaneous distance of the object from the origin at that point.
C average distance of the object from the origin at that point.
D instantaneous speed of the object at that point.
E none of the above is correct.

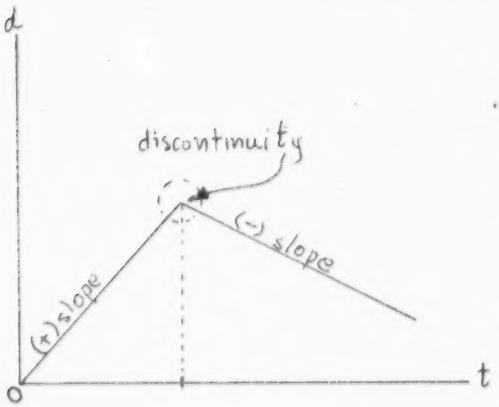
(Please return to page 49)

WORKSHEET

Please listen to Tape Segment 4 of Lesson 5 before starting this Worksheet. Use AV Computer Card in answering all questions.

DATA ITEM A: The diagram below.

QUESTIONS



12. What is the time duration of the point of discontinuity?

A A short time.
B A long time.
C Zero time.
D May be either short or long.
E At least one-tenth of a second.

13. When the distance-time curve of a real object goes from a positive to a negative slope, what must take place between the two differently sloped line segments?

A There must be an axial inversion.
B The object must speed up a part of the time.
C There must be a distance cancellation.
D The speed of the object must remain constant.
E The object must come to rest.

14. If a real body is receding from the observer at one instant and approaching him at the very next instant with zero time lapse for the change, then

A no time was allowed for the body to come to rest.
B the body will reach the observer faster.
C less time will be required for the return trip.
D we don't know what will happen because our data is inadequate.
E it would require higher mathematics to predict the effect.

15. A discontinuity in a distance-time curve is

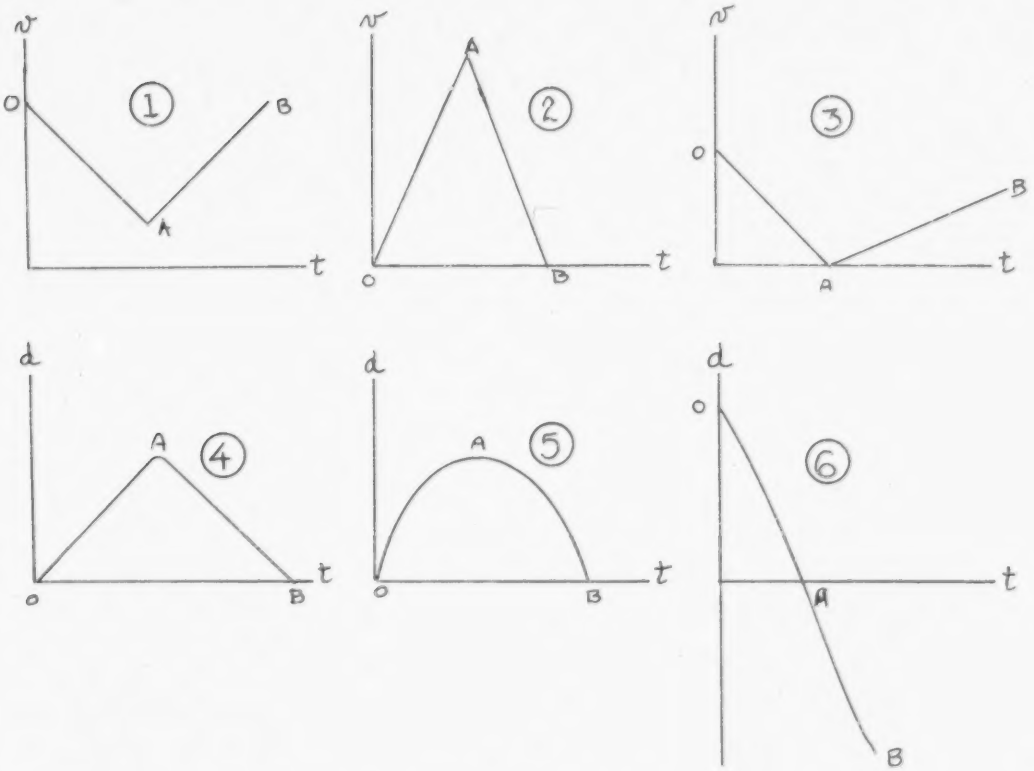
A physically possible. B physically impossible.
C possible under some conditions.

(Please return to page 23)

WORKSHEET

Please listen to Tape Segment 5 of Lesson 5 before starting this Worksheet. Use AV Computer Card for answering.

DATA ITEM A: Diagrams 1 through 6 below.



QUESTIONS

16. Which one of the graphs above correctly describes the v-t relationship of the ball going up and down the plane?

A Diagram 1 B Diagram 2 C Diagram 3
D Diagram 6 E None of the diagrams.

17. Which one of the graphs above correctly describes the d-t relationship of the ball going up and down the plane?

A Diagram 3 B Diagram 4 C Diagram 5
D Diagram 6 E None of the diagrams.

(Please return to page 27)

HOMEWORK PROBLEMS

1. Table 1 shows the distance traveled by a car over a 10-second time interval.

TABLE 1

Time (sec)	Distance (m)
0	0
2	35
4	70
6	105
8	140
10	175

(a) Plot the distance-time graph of the motion. Use standard linear graph paper.

(b) What does the graph reveal about the nature of the motion? Is it constant speed, changing speed, uniform acceleration, non-uniform acceleration, zero speed, etc?

(c) How far did the car travel at the end of 5.5 sec?

(d) Determine the instantaneous speed of the car at the 6th second of its journey.

2. A vehicle is moving at a constant speed of 20 m/sec.

(a) Plot its speed-time graph for a 10-sec interval. Use standard linear graph paper.

(b) Make a table of the distances traveled by the vehicle each two-second interval, starting with zero.

(c) Plot the d-t graph of vehicle's motion. Use standard linear graph paper.

3. A car moving at a constant speed of 15 m/sec is 20 m ahead of a second car moving at a constant speed of 20 m/sec. On a piece of standard graph paper (not to be submitted to instructor), plot the d-t graph of each of the cars using the same axes. Determine from this graph

(a) the time required for the second car to catch up with the first.

(b) the distance traveled by the second car during this time.

(Next page, please)

4. A train moving at a constant speed of 15 m/sec travels for 2 sec and is then uniformly accelerated for 3 sec at the rate of 2 m/sec^2. From a speed-time graph of this motion (need not be submitted) find

   (a) its speed at the end of 4 sec.

   (b) the distance it has traveled at that time.

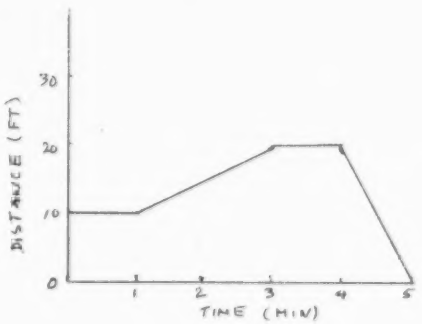
5. Referring to the d-t graph at the right, determine

   (a) the distance traveled by the body between the first and third minutes.

   (b) the distance traveled by the body during the first 3 min.

   (c) the average speed of the body during the first 3 min.

   (d) the average speed of the body for the first 4 min.



6. Referring to the d-t graph above at the right, find the following: (Be careful with algebraic signs).

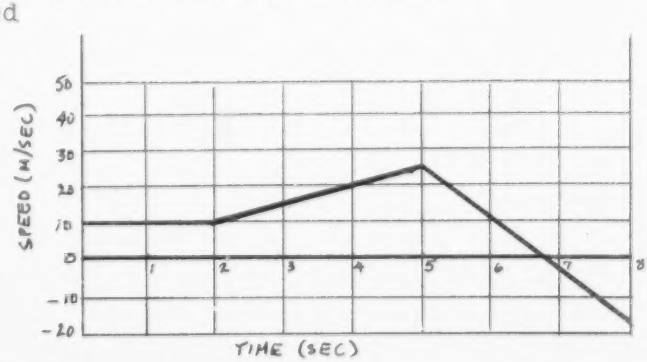
   (a) the speed of the body during the first minute.
   (b) the speed of the body during the interval between the first and third minute.
   (c) the speed of the body between the fourth and fifth minute.

7. Referring to the v-t graph at the right, determine how far the body traveled

   (a) between t = 0 sec and t = 2 sec.

   (b) between t = 2 sec and t = 5 sec

   (c) What is the average speed of the body for the first five seconds?



(next page, please)

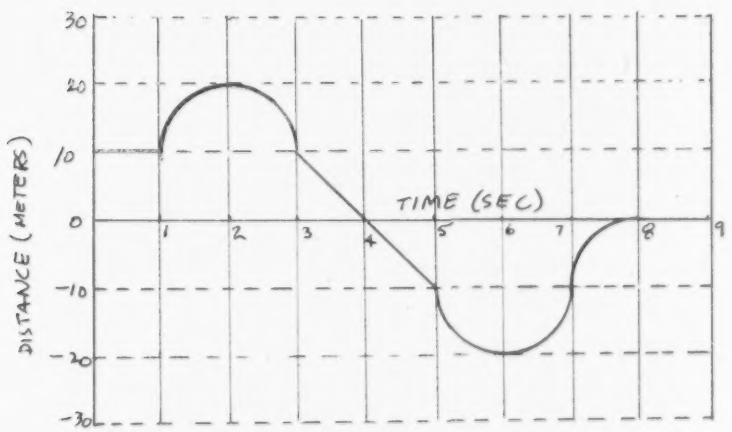
8. Referring to the same graph used in Problem 7, find the acceleration at the following times. (Watch signs!)

(a) t = 1 sec

(b) t = 4 sec

(c) t = 6 sec

9. Referring to the graph below, answer the questions relating to it.



(a) At what instants in time after t = 2 sec is the body at rest?

(b) Name the instants at which the body reverses its direction.

(c) Between what values of t is the body moving at a constant speed?

(d) Between what values of t is the body undergoing acceleration, either positive or negative?

10. A car traveled for 0.1 hr at 30 mi/hr and for 0.2 hr at 40 mi/hr. It then stopped for 0.1 hr and finally completed its trip in an additional 0.5 hr at 20 mi/hr. For your own use, plot a v-t graph of the motion, then determine from your graph (need not be submitted) the distance traveled at the end of

(a) 0.3 hr (b) 0.7 hr

(c) What was the average speed of the car during (a)?